Project no. 691735
REPLICATE PROJECT
Renaissance of Places with Innovative Citizenship And Technology

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

REPLICATE PROJECT

REnaissance of PLaces with Innovative Citizenship And Technology

Project no. 691735

H2020-SCC-2015 Smart Cities and Communities
Innovation Action (IA)

D7.3 Report on technical solutions v2

Due date of deliverable: 31/03/2019
Actual submission date: 10/04/2019

Start date of project: 01/02/2016 Duration: 60 months

Organisation name of lead contractor for this deliverable: SPES
Status (*Draft/Proposal/Accepted/Submitted*): Submitted

Project co-funded by the European Commission within the 7th Framework Programme		
Dissemination Level		
PU	Public	x
CO	Confidential, only for members of the consortium (including the Commission Services)	

Editor/Lead beneficiary:	SPES
internally reviewed by:	Tecnalia

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Index of contents

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

1. EXECUTIVE SUMMARY

The aim of Replicate lighthouses' pilot actions is to find innovative technologies and approaches to be extended and exported in other smart cities, starting with the followers and observers involved in the project.
During the implementation the measures included in the pilots' comprehensive sets have passed from the idea to reality, some of them going through adaptations due to the evolving framework and unexpected obstacles but collecting the first results and useful feedbacks.
The most interesting technical solutions belonging to the three sectors (energy efficiency in buildings, sustainable mobility and use of ICT) are illustrated in this deliverable by the responsible partners and the lighthouses to provide other cities and professionals with hints and ideas for the propagation of the results.
At this stage, the actions selected have been:

- ✓ District heating: new and updated systems
- ✓ Thermal energy storage
- ✓ Energy demand management systems
- ✓ E-taxi fleet and fast recharge
- ✓ Charging infrastructure
- ✓ E-bikes
- ✓ Mobility supporting systems: parkUs and Multimodal Journey planner
- ✓ High speed mobile network based on postWIMAX technology
- ✓ Smart grid
- ✓ Eco & Smart public lighting systems
- ✓ ICT, Smart City, mobility and citizens platforms
- ✓ Open data and Big data

The assessment of the replication potential has been carried out with the support of the KPIs set for smart cities' projects developed by CityKeys as reported in the conclusions.

The technical analysis will be supported by a study on the management models in use developed in D7.5.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

2. REPLICATE

The main objective of REPLICATE project is the development and validation in three lighthouse cities (**San Sebastián** – Spain, **Florence** – Italy and **Bristol** – UK) of a comprehensive and sustainable City Business Model to enhance the transition process to a smart city in the areas of the energy efficiency, sustainable mobility and ICT/Infrastructure. This will accelerate the deployment of innovative technologies, organizational and economic solutions to significantly increase resource and energy efficiency improve the sustainability of urban transport and drastically reduce greenhouse gas emissions in urban areas.

REPLICATE project aims to increase the quality of life for citizens across Europe by demonstrating the impact of innovative technologies used to co-create smart city services with citizens and prove the optimal process for replicating successes within cities and across cities.

The Business Models that are being tested through large scale demonstrators at the three cities are approached with an integrated planning through a co-productive vision, involving citizens and cities' stakeholders, providing integrated viable solutions to existing challenges in urban areas and to procure sustainable services. Sustainability of the solutions is fostered in three areas: economic and environmental and finally, fostering transparency in the public management.

In addition, the Model features the replicability of the solutions and their scale up in the entire city and in follower cities, particularly in three follower cities (**Essen** – Germany, **Lausanne** – Switzerland and **Nilüfer**–Turkey) that are involved in the project and therefore, have access to know-how and results achieved on the project so they can apply the developed model. At the moment, there are 2 observer cities, Guanzhou (China) and Bogota (Colombia).

3. INTRODUCTION

WP7 "cross cutting activities": aims and links

Work package 7 of Replicate project summarises the experience of the pilot actions providing materials for the following WPs (task 7.1 and 7.2) and extending the pilots with a concrete replication plan at city or metropolitan level (task 4): following the STEEP project experience, the three cities are working together, after the common planning phase and the recent test realisation phase in the field, to deliver a scalability analysis of the interventions (task 7.3) based on the concrete realisation results.

After the work done in the field (Lighthouses Pilot districts WP3,4,5), very valuable lessons in understanding the obstacles/results of the integrated measures set have been acquired: the three pilot actions have been analysed in detail and each city has also started thinking about the opportunities and barriers in replicating and scaling up this approach to the city level, but also in the other two cities contexts in order to have a wider landscape of the test phase.

The results from the technical comparison (D7.2 and 7.3 "Report on technical solutions") matched to the different management models and the business plans (D7.4 and 7.5 "Report on management

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

models") will offer the cities all the tools to develop reliable replication plans (D7.6 "Lighthouse cities replication plans").
The consortium has three assumptions:

- A district could be considered as a small city area where urban issues can be represented.
- The pilot in the districts will help to understand the complex system related to implementation of the integrated Smart City Plans.
- It is necessary to collate the knowledge of all stakeholders involved in the three pilots, to validate the relevance of the initiatives selected.

With these three assumptions, the objectives related to the cross-cutting WP are:

- Detect the optimal conditions for the replication of the solutions tested in the Smart districts in connection with industrial/SME partners
- Define the scalability potentials and the possible roadmaps for the extension of the pilot at city/metropolitan level
- Use stakeholders' knowledge for understanding, defining and validating interventions in the urban system.

Relation to Other Project Documents

Above the obvious close interaction with the three pilots (WP3,4,5), whose results and schedules it depends on, WP7 is strongly linked also to the other transversal workpackages regarding ICT platform and monitoring (WP6, 10) and it presents important synergies with the replication potential analysis at market sectorial level or in other follower cities (WP2, 8, 9).
In particular the following activities regarding learning from pilots (WP2 and 8), networking, replicability and exploitation potential are interested in data harvesting from pilots which is the main goal of this document.

Reference documents

This deliverable has interacted with the following project documents:

Ref.	Title	Description
REPLICATE GA signed 240713.pdf	Grant Agreement	Grant Agreement no. 691735
DoA REPLICATE (691735)	Annex 1 - DoA to the GA	Description of the Action
REPLICATE Consortium agreement	Consortium Agreement	REPLICATE project - Consortium Agreement
REPLICATE WP1 project management	D1.7 Data Management Plan	REPLICATE - data management plan
REPLICATE WP2	D 2.2 Business Models of the Lighthouse cities	First description of the BMs adopted

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

REPLICATE WP3 San Sebastian Pilot	D3.3 District Heating	Report on DH implementation in SS
	D3.8 Smart mobility platform	Report on smart mobility platform deployment
	D3.9 electromobility monitoring	Report on electromobility
	D3.10 High speed network based on post WIMAX technology	Description of the high-speed network implemented
	D3.11 Smart Lighting	Report on smart lighting
REPLICATE WP4 Florence Pilot	D4.1, D4.3 Periodic Reporting on the state of the implementations in Florence.	Florence Energy Pilot – Report on the state of the project
	D4.2, D4.4 Pilot action measures advancement sheets	Monitoring report of the pilot at M18 and M30
	D4.6 ICT pilot architecture D4.7 Replicate platform D4.8 Replicate dashboards D4.9 Replicate Apps	Reports on ICT measures
REPLICATE WP5 Bristol Pilot	D5.3 ENERGY DEMAND PLATFORM DEPLOYED TO MONITOR ENERGY GENERATION AND DEMAND	Report on EDMS action
	D5.4 Twelve E-bikes Deployed in a Corporate Scheme	Report on e-bikes deployment
	D5.5 Expansion of a Car Club in the Area with Electric Vehicles	Report on car club action
	D5.7. Transport Infrastructure Adaptation Including EV Charge Point Installation	Report on transport infrastructure adaptation
REPLICATE WP6 ICT Platform	D6.4 Integrated architecture and services catalogue	Description of the 3 pilots ICT platform and services
REPLICATE WP7 Cross cutting activities	D7.1 Peer review methodology	Description of the City Data Canvas developed
	D7.2 Report on technical solutions v1	Pilot actions technical solutions analysis

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

	D7.5 Report on management models v2	Pilot actions management models analysis
REPLICATE WP9	D9.1 Baseline definition and integration and results analysis from WPs 3,4,5,8	Baseline for the 3 pilots
	D9.2 Methodology review and methodological framework definition	Business models analysis methodology
REPLICATE WP10 Monitoring	D10.1 Report on indicators for monitoring at project level	Set of indicators to assess each Replicate project intervention
	D10.2 Report on indicators for monitoring at city level	Set of indicators to assess the impact of interventions at the city level
	D10.3 Baseline analysis of city level indicators for follower cities and benchmarking with lighthouse cities	Evaluating the baseline analysis of city level indicators for follower cities and benchmarking with lighthouse cities.

In the event of discrepancy between documents, WP7 Materials are overruled by the contract with the EU (Grant Agreement) including its Annexes and amendments, which takes precedence over all other documents.

Abbreviations list

ADS	San Sebastian municipality (Ayuntamiento Donostia San Sebastian)
BCC	Bristol City Council
CA	Consortium Agreement
GA	Grant Agreement
DoA	Annex I-Description of the Action
DH	District Heating
EC	European Commission
EDMS	Energy Demand Management System
RES	Renewable Energy Sources
SCCR	Smart City Control Room
TES	Thermal Energy Storage
WP	Work Package

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

4. DELIVERABLE DESCRIPTION

Starting from the peer review methodology, described in D7.1 and summarised in annex 2, this deliverable will exploit the info collected to exchange feedbacks among lighthouses (breaking silos) and to carry out further analysis by experienced partners to describe in detail, validate or adapt the technologies tested in the pilot district for the scale up and replication phase.
The description of the framework together with the measurement of city performance is one of the critical ways in which we can assess the complexity of urban change, and judge which approaches are successful or not; the analysis, common to the management models report D7.5, will report the changes that have been occurred in the three cities' context since the proposal phase to assess their influence on the implementations and to evaluate the adaptations adopted by the lighthouses.
In a fast-evolving economy is necessary to keep on learning about city strengths and weaknesses to be more and more flexible and to adapt the planned measures in order to optimize the results and the impacts for citizens.
For this technical solutions analysis at the end of the pilot actions, the three cities have been asked to select the most significant and innovative measures whose technologies play a central role.
The actions selected are described under the present document which covers:
Section 5: the current framework
Section 6: the methodology adopted
Sections 7-13: analysis of the pilot measures and first scale up analysis
Section 14: Replication potential
Annexes: - Overview of the pilot actions and partners list
- The methodology (with abstract from Citykeys D1.4)

5. The fast-evolving framework

Lighthouses, as every smart city, are based on a very dynamic environment following closely societal and technological evolution and at the same time they are located in multilevel national systems with own policies and strong influences in some sectors. It has been three years since the development of the project idea or even more since the definition of the actions with the participatory processes and in the lighthouse cities the framework has slightly changed influencing the actual implementation. The analysis of the changes from the national to the local level has become important to understand the adaptations and the optimal conditions for the replication/scalability of the measures.
In annex 1 of D7.5 ("Report on management models v2") is reported a short update from the three cities to contextualize the actions and a focus on energy prices as well as the status of the ESCO market in the three nations.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

6. The methodology adopted

The project consortium can count on a relevant number of Smart Cities stakeholders experienced in different fields: it was necessary to collate the knowledge of all partners, to validate the relevance of the initiatives selected.
Since the definition of the peer review template, many partners have been involved: starting from the lighthouses (the main user addressed), feedbacks have been asked to technical partners (Tecnalia, University of West England) and interested WP leaders (ESADE business school, the two universities of Oxford and Exeter) but also to the three follower cities.
Technical partners with specific skills have provided feedbacks about the other lighthouses choices and the measures reported have been discussed among the consortium also during the General Assembly and the face to face meetings occurred or in specific virtual sessions organised on WebEx.
The actions have been shared and the discussion open to any interested partner (especially with followers) with the aim of cross fertilising the scale up and replication plans to be developed in the next years. A follow-up activity is already foreseen within the city-to-city learning program started in the early 2019.
In this document the sections of the City Data Canvas much related to the technical implementation have been detailed and analysed, while the replication and scalability KPIs, developed together with the partners in charge and the respective lighthouse, have been used to draw radar charts to support the comparison.
In annex 2 a more detailed description of the methodology adopted including:

- The city data Canvas from D7.1
- The replication KPIs

7. SMART BUILDINGS:

In this section the actions aimed at increasing the energy efficiency and the comfort in buildings have been illustrated. The main solutions selected by the cities regard the District Heating with renewables exploitation and the Energy Demand Management with the support of ICT technology.
In the case of the District heating different approaches have been adopted combining or not the intervention with the buildings retrofitting and deploying a brand-new system or revamping an existing one.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Solution 1: New District Heating

Main partners involved: Fomento de San Sebastian, ADS (San Sebastian Municipality)

Short description of the action

The District Heating (DH) project in San Sebastian provides a system for distributing heat, powered by biomass, for Domestic Hot Water and heating generated in a centralized location through a system of insulated pipes for the new residential area Txomin Enea (160.000 m2). The framework for this project spans the development of the DH building, installation, setup, operation and maintenance. It should guarantee continuity and quality of the thermal energy supply to meet the heating and DHW demand of 1,458 homes, including the connection of 156 retrofitted houses. For this purpose, the installations are composed of two biomass boilers (1400 kW) and two gas boilers (2300 kW).

DH is the largest woodchip/biomass-fired power plant in the Basque Country. When the neighbourhood is fully occupied, the plant's total energy efficiency will be above a record-breaking 90% in combined hot water and heat mode. For decentralised boiler systems, efficiency is usually around 55%. The project will deliver better results in terms of performance, energy efficiency, and greenhouse gas emissions than a decentralised boiler system.

Furthermore, an operation platform has been developed to control the demand side through ICT, allowing residents to monitor their consumption.

Value proposition

Fomento de San Sebastián started heading up the DH development project for Txomin neighbourhood in the year 2010, a highly innovative project for the city and region, and the first publicly owned DH system in the Basque Country.

The project brings benefits of different kinds:

- environmental benefits, for the use of renewable energy (biomass) and the reduction of CO_2 emissions. Moreover, the centralized system has more efficiency than decentralised boilers, which means a reduction in energy consumption.
- economic benefits thanks to a lower spending on preventive maintenance (carried out by specialist staff), a lower spending on primary energy procurement (used to generate thermal energy) and fewer incidents and therefore lower spending on corrective maintenance.

Beside this, users benefit from various advantages:

- 15% savings on the price of the thermal energy consumed
- Non-individual maintenance actions for each building
- Greater guarantee and quality of service, and its availability
- Reduction of investment required in each building.
- No need for each dwelling to have its own central heating system and gas mains connection
- No need to invest in the building's gas network
- Better use of floor space in each building.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Technology

The district heating systems includes the following equipment for heat production, mainly:

- Two redundant biomass boilers (1400 kW) to guarantee service delivery,
- Two redundant gas boilers (2300 kW) to guarantee service delivery, with their respective related equipment.
- Hydraulic networks and primary pumps from the boiler equipment up to the pipes.
- Hydraulic networks and secondary pumps for water distribution, up to the limit of the thermal power station

As for the two boilers of 1400 kW, these are equipped with flues, for a maximum working pressure of 6 bar. The boiler has a regulation system, so that the thermal output of the boiler is automatically adjusted to the consumption of heat.

The system also controls the boiler input and output temperature, the condition of the fuel bed, the light barriers of the intake system, exhaust gas temperature, the oxygen content of the exhaust gases (Lambda probe), and the temperature of the buffer tank, through a system of 3 or 5 probes. Through the use of a digital power modulation system, the boiler achieves output levels of 90 – 92%.

The biomass boiler has two attached filtering systems, a multi-cyclone separator for larger particles, and an electro-filter, which enables the filtering of fine particles to avoid environmental emissions.

Rated Power: 1,628 KW
Heat output: 1,400 KW
Minimum output: 350 kW
Length: 4,242 mm
Width: 1,900 mm
Height: 4,505 mm
Weight: 21.422 kg
Volume of water in the boiler: 3,720 l
Permitted service pressure: 6 bar
Maximum operating temperature: 100 °C
Flue Connection: 630 mm

Figure 7.1 – the boiler

The exhaust gas separator minimises dust emissions by the filtering exhaust gases using a multi cyclone system. As a second filtering system, dry electrostatic filters are used to separate out suspended solid particles in the biomass combustion gases.

The non-hazardous waste produced is handled and transported to a licensed landfill by an authorised manager in the Basque Country.

The biomass that is used in the Txomin district heating system is wood chips. This must be certified biomass and must meet the requirements by certification systems that guarantee sustainability. It

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

must be local biomass, collected from forests located at no more than 250 km from the point of delivery.

The hot water boilers intended for the production of hot water, in support of the principal biomass production, are pyro tubular boilers for the production of the hot water for permissible flow temperature up to 95ºC of mono-block construction and horizontal configuration. They are by the VIESSMANN company, Vitomax 200-LW M62C model with heat exchanger Vitotrans 300 model.

The boiler is a three-pass boiler with a large heating surface that gives a high resource efficiency (from 92% to 95,5%).

To reduce the loss of thermal energy due to transmission (radiation and convection), the generator body is thermally isolated with high density glass fibre 120 mm thick and externally protected by a metallic cover made of completely painted steel sheet. Frontal insulation is a ceramic fibre of low thermal conductivity.

Lastly, the Natural Gas burner is made up of the automatic burner with a regulation of the modulating heating supply, mono-bloc type, functioning with natural gas. With a maximum power of 2725 kW and minimal power of 743 kW.

In order to ensure the correct functioning of the District Heating system, there is a Computer-Assisted Maintenance Management System (CMMS), encompasses all the elements associated with the generation of heat via the District Heating system, network of pipes, and the buildings installations right up to the user module in each home.

The building hosting the boilers is integrated into the new residential estate near the river park and has been designed in order to be well integrated in the landscape.

Figure 7.2 – the building

Innovation Level:

Although very common in many countries, this development is the first of its kind in the Basque Country and therefore a good test for the potentiality of these types of interventions.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Main impacts

Direct impacts

Thanks to the DH project for Txomin-Enea, CO2 emissions will be reduced by 80% compared to individual heating and hot water systems. The project will drive emissions down from 2,900 tonnes of CO2 emitted per year with conventional heating, to just 450, which within a period of 20 years would lead to a reduction of almost 50,000 tonnes.

Users can benefit from 10-15% savings on the price of the thermal energy and non-individual maintenance actions for each building.

Indirect impacts

The project can boost the users' awareness on energy consumption and lead to a more rational use of energy among them.

Market analysis: enablers and obstacles

Legal framework

Below is a list of the main regulations that apply to the District Heating project.

- UNE-EN ISO 17225:2014 Solid Biofuels - Fuel specifications and classes.
- Royal Decree 1042/2017, of 22 December, regarding the limitation of emissions of certain pollutants from medium combustion facilities, updating appendix IV of Act 34/2007, of 15 November, regarding air quality and protection of the atmosphere. The purpose of this Royal Decree is to incorporate into Spanish law EU Directive 2015/2193 of the European Parliament and the Council of Europe, of 25 November 2015, on the limitation of emissions of certain pollutants into the air from medium combustion facilities.
- The Regulation for Thermal Installations in Buildings (RITE) sets out the conditions required for the installations designed to meet the demand for thermal comfort and hygiene through heating, air-conditioning and hot water installations, to achieve a rational use of energy.
- The Technical Building Code, current regulation in the period of definition and development of the DH project, approved by Royal Decree 314/2006, of 17 March. The Technical Building Code (TBC is the regulatory framework that establishes the requirements that must be met by buildings in relation to the basic safety and habitability requirements established in Act 38/1999 of 5 November, regarding Building Regulations (LOE). The basic quality requirements with which buildings must comply relate to matters of safety and habitability. The TBC also addresses accessibility as a result of Act 51/2003 of 2 December, regarding equal opportunities, non-discrimination and universal accessibility for persons with disabilities, LIONDAU.
- The Energy Performance of Buildings Directive 2010/31/EU adopted on 19 May 2010
- Additional Building Regulations specific to San Sebastian City Council

Incentives

The economic and management of the District Heating model consist on a public-private collaboration with the aim to generate a management system that allows aligning public and private

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

sector objectives, while guaranteeing public policies, energy prices stability and maintenance for final users.

The service is owned by Fomento de San Sebastián, S.A., in other words, the City Council itself will be involved in day-to-day management through a strict monitoring of service quality and the requirements set out for the operator in the tender competition process.

It has been decided that any energy not consumed should be charged in a differentiated way, at a price that only covers the cost of the primary energy required to produce it. This means that Fomento de San Sebastián, in its business plan, assumes this cost, and it is not reflected in the fixed price defined for users, protecting people and families who require more energy consumption (older people or large families).

Human factor (success factors, opposed sentiments,…)

The main success factors consist in savings (-10/-15%) on the actual energy costs, less responsibilities (no more private boilers) for tenants and RES implementation with consequent GHG reduction.

During the project development, different difficulties were encountered: in fact it is the first DH project for the Municipality and first publicly owned DH system in the Basque Country. Moreover difficulties were faced to ensure compliance with a sustainable business plan. In addition, the variables of demand and necessary investment, as well as the quality of the service that is to be lent, generated doubts about the suitability for the San Sebastián City Council.

For its approval, it has been key to have found financing channels, the public-private collaboration model defined, and a sufficient number of dwellings built in the Txomin neighbourhood to be connected to the DH.

Competitors

Autonomous gas boilers or HPs, centralised gas boilers, biomass plants.

First scale up analysis:

Lessons learnt

For the successful implementation of the DH system, the involvement and the support several experts have demonstrated to be essential. It has been necessary to ensure compliance with all requirements from the public point of view, not only for the study of feasibility, contracting, construction and commissioning, but also in the following years during the monitoring phase.

The conditions included in the contract with the Txomin Enea UTE contemplate different tests and audits to guarantee the level of service and compliance with the established environmental requirements.

Certainly, Txomin District Heating plant is already a best practice and an innovative case study for other cities interested in implementing similar systems, and above all, the business model proposed is also very different from traditional concession formats.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Optimal scale for next implementations

In terms of scalability, the construction of neighbourhoods of this same number of housing in San Sebastian is not usual, however there is an urbanisation plan for two areas of the city with enough planned housing, as to raise the viability of heat plants of these characteristics. So, the intervention can be replicated in new urban developments in the city, while replicating in existing districts seems more complicated.

Further developments needed

In advanced economies, a limit to the DH development is represented by the low rate of construction of new buildings, while in emerging countries the DH have a wider dissemination potential. For this purpose it is very important to try to develop, test and optimize economically sustainable DH while retrofitting existing complexes. A key role is played by policy measures and incentives.

Expected impacts in the next future

The replication of DH system powered by biomass could support the exploitation of renewable energies, contributing to GHG savings due to building sector in critical environments.

Solution 2: District heating upgrade

Main partners involved: Bristol City Council (BCC)

Short description of the action

The heat network connection would allow two thermal demand profiles (domestic in Broughton and office in 100 Temple St) to be matched, improving the viability of gas CHP and making the most of the existing thermal generating assets. The connection will link the 1 MW biomass boiler with a 0.8 MW Gas CHP and 3MW of peak and reserve gas boilers (to be installed in autumn 2019). The work allows the potential for the network to serve in the next future another 17MW of heat demand locally.

The scheme focusses on the areas of Redcliffe (Broughton House) and 100 Temple Street. It aims at connecting a separate existing heat network to Council offices in 100 Temple Street which can partake in holistic energy demand management and enable future connections to this network.

Value proposition

In the UK, only about 2% of heat is supplied via heat networks; one of the lowest levels in Europe. UK Gov has set a target of 30% of heat to be supplied by heat networks in 2030, representing a 15-fold increase over thirteen years. Some European countries have over 60% of their heat supplied via heat networks; and some cities as high as 95%.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Bristol has an official target to be a carbon neutral city by 2050 and local politicians have resolved to attempt to reduce this target to 2030.

Technology

The solution in use

Heat production:

1MW Wood Pellet Boiler supported by 3.5MW of gas boilers (back up) at Broughton (existing); plus a 1MW gas CHP plant is currently being investigated at 100 Temple Street. As more connections are added, further heat generation is likely to follow this trend in the short term (combination of gas CHP, boilers and wood heating); until, due to the scale of demands, larger thermal generation technologies become possible, BCC has completed feasibility for 2 Water Source Heat Pumps in the city centre as well as masterplannig for a wider network that will include Energy from Waste and, heat recovery.

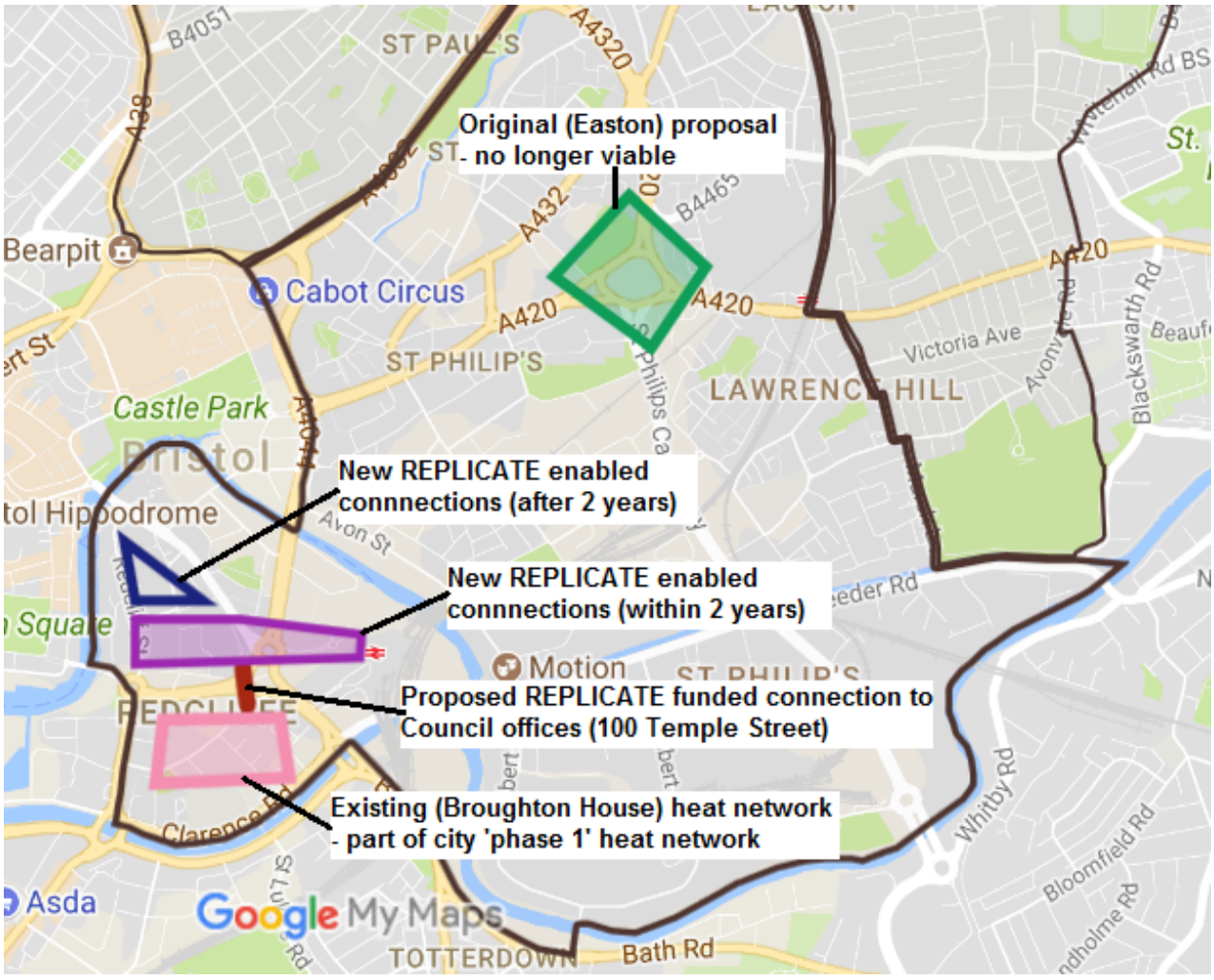


Figure 7.3 District Heating in REPLICATE district

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Building Management System:

Existing Building Management System will be optimised to accommodate these additional points:

Pumps		**SIP**
	Differential Pressure Sensors (5 No. From Pumps)	5
	Pump integration by Modbus (12 No. Pumps)	60
Biomass Integration	Biomass System Integration by Modbus	5
Pressure System Integration	Pressure System Integration by Modbus	5

The following control equipment has been supplied:

2 No. Modbus Integration Controllers.

2 No. mBus to Modbus Converters

1 No. Head-end BMS PC, including IQVision software with licences (up to 2500 points, 1 year software maintenance update, Export to CSV - Excel integration, SQL communication).

The municipal department has engineered and commissioned the control system detailed above following the Mechanical and Electrical Installation, including:

- Set up pump speed control based on differential pressure sensors.
- Integration of additional meters to BMS
- Setup of trend logging for all Input/Outputs w/1 Year History.

Innovation

District Heating for this scheme to help decarbonise the grid has a high innovative approach within the UK and southern Europe, unlike areas in northern Europe where the technology is more tried and tested. Additionally, there is innovation potential on heat networks, for example in areas such as heat interface units and smart meters, as this could create further jobs across the UK and open up opportunities for international trade.

Finally, Bristol is innovating with scale up models via another supporting energy programme called City Leap which is hoping to attract over 300m investment into the future heat network and the work of this project will add to the leverage factor required to do this. A proposal for City Leap is being presented to the Council Cabinet for approval in early April 2019.

Main impacts

Direct impacts

The Biomass boiler has already protected social housing tenants (some of the poorest in the city) from a 25% increase of wholesale gas prices in the last 12 months. The combination of the pipe connection and the controls installed as part of this project will bring further efficiencies on the existing social housing network and provide more efficient gas-powered heat from the CHP further protecting residents for fuel price increases and may even reduce bills in the short term.

The use of the CHP boiler to displace the peak and reserve gas boilers both on the existing network will bring further savings due to the efficiencies of the CHP heat production.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

The Project is also supporting the Councils internal carbon target of reducing is carbon use by 65% against a 2005 baseline by 2020. (Note: the BCC has already achieved this target two years early and is currently at a 71% reduction and is striving to reduce further)
The new connection itself is expected to save up to 255 tonnes of annual CO_2 savings.
The Biomass boiler in Broughton House and back-up boilers currently have excess demand. By completing these works, it allows for the excess demand from the existing technology to be transferred into a further network in the Redcliff part of the city. The system will supply offices as well as further residential dwellings, meaning that the carbon savings will increase over time. By having offices as well as residential, it means that the there is a better diversity on the system (e.g. offices need heat in the day and residential needs heat in the evenings and weekends). This means that the current equipment can run more efficiently for more of the time.
Through economies of scale, The Bristol City Council Redcliffe Heat Network aims to reduce the capital expenditure of new developments by 10%. It also aims to reduce the overall cost of heat for customers by 5% against avoided costs such as boiler maintenance. Bristol City Council works with developers to ensure that their buildings are designed and built to the highest of standards through energy and heat efficiency.
As well as this, by installing a new CHP plant within the basement of 100 Temple Street and transferring heat backwards and forwards to Broughton House, it means that the entire system is more resilient in the future. This is particularly true against standard boilers on a communal system within a building.

Indirect impacts

• Increased security of supply as it will connect two energy centres within a central location under the control of Bristol City Council
• The ability to offer connection for hard to treat properties including historic properties within Bristol centre.
• Providing a larger scale heat network with a mix of public and private users, large and small scale developments, new and historic buildings, as an example for other local authorities and developers going forward.
• Improve viability for a low carbon Bristol and the Mayor's commitment to put Bristol on course to be entirely on clean energy by 2050.

Enablers and obstacles

legal framework

Procurement of consultants to support delivery & contractors. Procurement is under OJEU limits but is governed by national Public Procurement Regulations and internal policy. Local planning policy now requires connection to DH networks where they are in a heat priority area such as Redcliffe. The use of this policy is becoming effective with developers and is critical to the business cases of the wider network. BCC has drawn up a set of legal documents to aid this process that include connection agreements, heat supply agreements and adoption agreements (where BCC is to adopt the secondary side of heating plant within buildings.

Incentives

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

The incentive of this scheme is to produce low carbon heat across the city and help make Bristol carbon neutral by 2050. Heat Networks are also a key part of this within the wider City Leap Programme.

Human factor (success factors, opposed sentiments, …)

Success Factors: This project is highly reliant on contractors and sub-contractors, each working independently and alongside each other. As the project is a network, then if one section is delayed such as the control system, then the whole scheme is delayed. Different highways contractors are working on different sections of the network and delays could have knock on effects to roadworks. Furthermore, consultants and contractors are designing and installing the control system which is being scaled up to incorporate the heat sources across two sites.

Equally the true extent of the success of the project will not be understood until it has been running for a full year. The scheme will need to go through at least one whole winter of transferring heat before the amount of carbon saved can be calculated.

Opposed Sentiments: Many believe that electric heating is more efficient and uses much less carbon than district heating. While this is strictly true – particularly as much of the electricity comes from low carbon sources such as wind turbines and solar panels – there are two main issues with this.

Firstly, if all new developments moved to electric heating, then this would put too much pressure on the demand of the grid. There isn't enough electricity being generated to cope with the current demand and heating. This is particularly true with the increase in electric cars coming into the market. Secondly the cost of heat. The cost of electric heat is approx. 3 times as expensive as heat from a heat network per kWh. This massively impacts customers and could push them into fuel poverty.

Competitors

There are no other competitors who could deliver this measure. The project is linking an existing network owned and operated by BCC to a building owned by BCC. BCC is reluctant to hand over strategically important assets to the private sector. Nationally there are private heat network operators but currently there are not any privately owned heat networks between buildings in separate ownership in Bristol.

First findings and scale up analysis

Lessons learnt

Since the submission to implement district heating in Bristol, there has been a number of abrupt and unexpected changes to renewable energy subsidies and housing policy. This has impacted on projects linked to the REPLICATE Project and has affected the business case on which the original district heating scheme was based.

The two significant policy changes that have made the original district heating proposal (in Easton) no longer viable are;

1) A reduction in rent revenue from the Council's social housing meaning that there is significantly less funds available to convert housing blocks from electric heating to a 'wet' system. This work is required for the original proposal.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

2) A 45% reduction in the Renewable Heat Incentive (RHI) subsidy for this type of biomass boiler. More detail on each of these is in the next section:

The original proposal was to build a wholly new biomass fuelled heat network connecting six housing blocks, a school and leisure centre. REPLICATE funding was specifically for the purchase and installation of a 1MW biomass boiler, with other capital funding from the Council paying for the conversion of housing blocks to a 'wet' heating system and for installation of piping connecting to the biomass boiler.

Optimal scale for next implementations

In the future, this new connection will enable up to 4,000 tonnes of annual CO_2 savings through additional connections during the life of the project and beyond. These additional connections are not part of the new proposal as they will be funded separately but would not proceed without the proposed REPLICATE connection.

As previously stated, the local planning policy supports the scale up of the network ensuring that new buildings and developments connect to the network. Once the network is built out there then is clear opportunity to connect to existing building as and when there existing heating plant (equipment) reaches the end of the useful life) projections in the business case show that connection to the heat network will provide customers with savings. BCC is committed to providing heat from the network at a lower net cost tan an equivalent gas connection.

There are no other district heating initiatives of this scale available in the target district. As the original proposal is no longer deliverable, this is considered a good alternative given the potential savings. In summary, the initial scale of the REPLICATE specific work has been reduced, but the new proposal more closely aligns to city objectives as it enables greater demand balancing and enables even greater CO_2 savings overall with a larger scope for scale up.

Expected impacts in the next future

The initial connection supplying heat to 100 Temple Street will be 100% renewably fuelled from the existing 1MWth wood pellet boiler.

The CHP will provide a balanced load with the Biomass boiler to the BCC offices and the operational network depending on a variety of factors: it is envisaged in the future that the controls system will also take into account things such as local air quality and electricity prices (when WSHP are operational) to switch between the various heat sources.

Additional buildings, connected via additional pipe branches from the main REPLICATE-funded pipe (see map below), are likely to be heated by a gas CHP from a proposed installation in 100 Temple Street.

These additional pipe branches are facilitated by the REPLICATE connection to 100 Temple Street, but they would be funded through a combination of heat sales and developer contributions. Where economically viable, the CHP fuel input will be biogas – regular reviews to ensure heat customers are not overcharged will be required for this.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

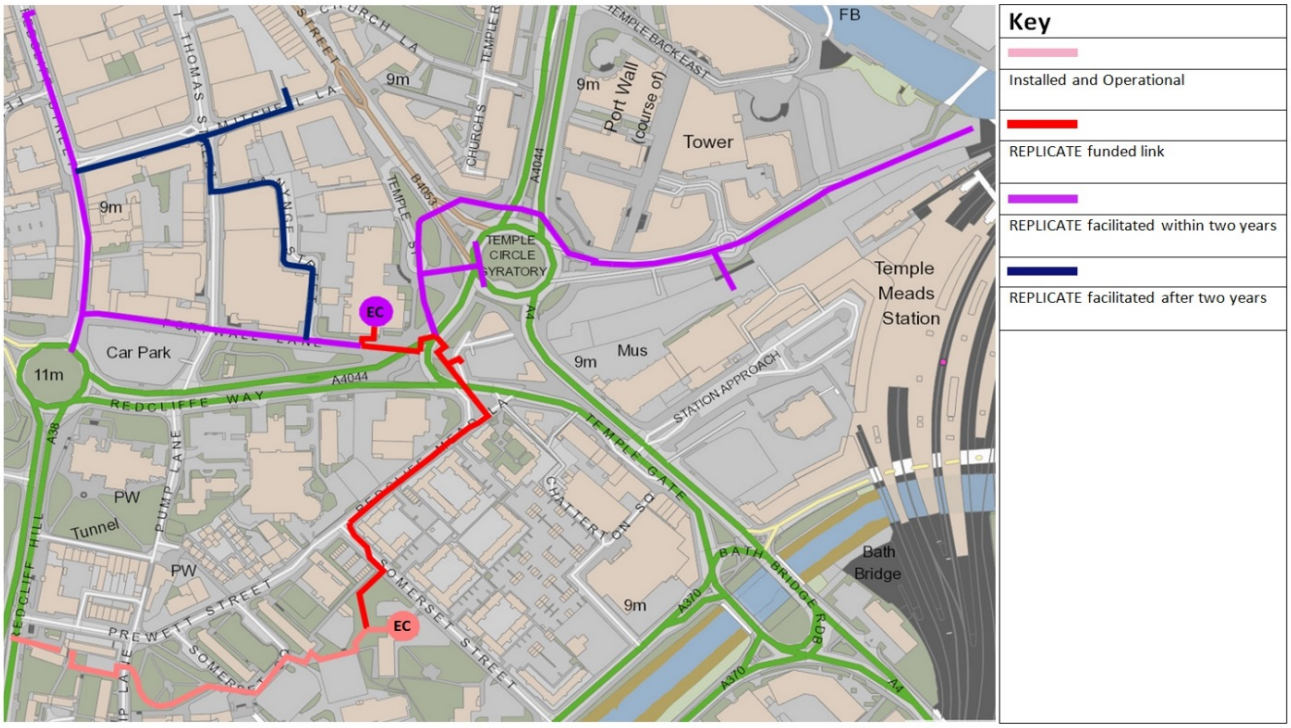


Figure 7.4: Detailed map of energy centres and connections

Bristol City Council is installing a 200DN pipe at a capital cost of 1.4m euros that will allow the heat network to grow further to connect to other nearby buildings. These different buildings are summarised in table 1 below.

ID	Type	Building Name	Sector	Base heat demand kW	Annual heat supply from DH
14	Existing – office	100 Temple Street	Public	607	1,013,433
P13	New – mixed use	Redcliff Quarter	Private	1,462	6,057,770
190	New – offices	Redevelopment of Brunel Mile	Private	779	1,801,990
191	New – offices	Redevelopment of Brunel Mile	Private	49	75,436
192	New – offices	Redcliff Wharf	Private	1,481	3,427,690
TM02	New – offices	Temple Circus Development	Private	298	456,960
TM03	New – offices	Engine Shed 2	Public	484	935,693
22	Existing – resi	Freshford and WCA House	Public	131	201,385
151	Existing – office	Redcliff Quay	Private	357	548,352
152	New – resi	2 Mitchell Lane	Private	168	258,048
158	New – offices	Arup (63 St Thomas St)	Private	125	191,601
161	New – offices	Portwall Place	Private	616	946,176
170	Existing – office	Bristol Justice Centre	Public	196	301,056
TQ04	New – offices	Old Breat Site (plot ND6)	Public	282	414,547
Tm05	New – offices	Templegate Peugot	Public	411	605,219
Totals				7,446	17,235,356

Figure 7.5: List of future district heating network connections enabled by Bristol Pilot

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Solution 3: Thermal Energy Storage for RES integration in a small DH

Main partners involved: City of Florence, Casa Spa, UNIFI, SPES

General description

The intervention consists in the retrofitting of two residential social housing buildings. The total surface selected is about 20.000 m² with an actual consumption of 3 GWh.

Figure 7.6- the Piagge buildings

The main objective of the intervention is the disposal of old existing individual heating systems, with a high performance micro DHS producing energy with high efficiency and RES exploitation through an innovative solar thermal seasonal storage. The network reaches the flats where the single boilers have been replaced with small heat exchangers without disruption for the tenants who will benefit from the change in terms of maintenance and energy costs.

The challenge consists in increasing the efficiency of residential buildings realizing such an innovative plant in a difficult urban environment (regulatory constrictions in such an urban area as Florence, low income users, single boilers replacement,…) to demonstrate its replicability in more favourable boundary conditions.

The preliminary study and the design phase have been supported by materials from IEE SDHplus (Solar District Heating) and FP7 Einstein (Effective INtegration of Seasonal Thermal Energy storage IN existing buildings) projects.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Value proposition

The energy demand required in residential sector, both electric and thermal, represents an important part of the consumption of primary resources (according to the latest evaluation of the municipality of Florence, over 53% of primary energy is used in buildings and 25-30% in the residential sector). Solar energy is certainly the most available and distributed renewable source in the context of urban areas but while photovoltaic technology is now sufficiently mature and already sufficiently applied widely, solar thermal technologies could be more and more exploited thanks to new panels developments but also to new configurations and solutions foreseeing the integration with storage systems.

Thermal energy storage (TES) is a technology that stocks thermal energy by heating (or cooling) a storage medium so that the stored energy can be used at a later time for heating applications and power generation. TES systems are used particularly in buildings and industrial processes. In these applications, approximately half of the energy consumed is in the form of thermal energy, the demand for which may vary during any given day and from one day to next.

Therefore, TES systems can help balance energy demand and supply on a daily, weekly and even seasonal basis. They can also reduce peak demand, energy consumption, CO_2 emissions and costs, while increasing overall efficiency of energy systems. Furthermore, the conversion and storage of variable renewable energy in the form of thermal energy can also help increase the share of renewables in the energy mix.

The implementation in Florence will represent a best practice for this technology in case of existing buildings blocks in city centres (first example in Italy).

Energy consumptions will be monitored in order to improve the system management and the users' awareness: a smart info system and a gaming APP will be made available to the tenants to monitor electricity and heating demand.

Technology

The solution in use

There are three kinds of TES systems, namely: 1) sensible heat storage that is based on storing thermal energy by heating or cooling a liquid or solid storage medium (e.g. water, sand, molten salts, rocks), with water being the cheapest option; 2) latent heat storage using phase change materials or PCMs (e.g. from a solid state into a liquid state); and 3) thermo-chemical storage (TCS) using chemical reactions to store and release thermal energy.

Sensible heat storage, the one chosen in our case, is relatively inexpensive compared to PCM and TCS systems and is applicable to domestic systems, district heating and industrial needs. However, in general sensible heat storage requires large volumes because of its low energy density (i.e. three and five times lower than that of PCM and TCS systems, respectively). Furthermore, sensible heat storage systems require proper design to discharge thermal energy at constant temperatures.

The use of hot water tanks is a well-known technology for thermal energy storage. Hot water tanks serve the purpose of energy saving in water heating systems based on solar energy and in co-generation (i.e. heat and power) energy supply systems. State of the art projects have shown that water tank storage is a cost-effective storage option and that its efficiency can be further improved

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

by ensuring an optimal water stratification in the tank and highly effective thermal insulation.

Large hot water tanks are used for seasonal storage of solar thermal heat in combination with small district heating systems. These systems can have a volume up to several thousand cubic meters (m3). Charging temperatures are in the range of 80-90°C.

A TES system's economic performance depends substantially on its specific application and operational needs, including the number and frequency of storage cycles. In mature economies (e.g. our countries), a major constraint for TES deployment is the low construction rate of new buildings, while in emerging economies TES systems have a larger deployment potential.

TES systems based on sensible heat storage offer a storage capacity ranging from 10-80 kWh/t and storage efficiencies between 50-90%, depending on the specific heat of the storage medium and thermal insulation technologies.

The cost of a complete system for sensible heat storage ranges between €0.1-10/kWh, depending on the size, application and thermal insulation technology: TES systems for sensible heat are rather inexpensive as they consist basically of a simple tank for the storage medium and the equipment to charge/discharge. Storage media (e.g. water, soil, rocks, concrete or molten salts) are usually relatively cheap. However, the container of the storage material requires effective thermal insulation, which may be an important element of the TES cost. A number of seasonal TES have been installed in EU. Most systems consist of a 5,000-10,000 m3 water container with energy content between 70-90 kWh/m3 and investment costs between €50-200/m3 of water equivalent, thus translating into a specific investment cost from €0.5-3.0 per kWh.

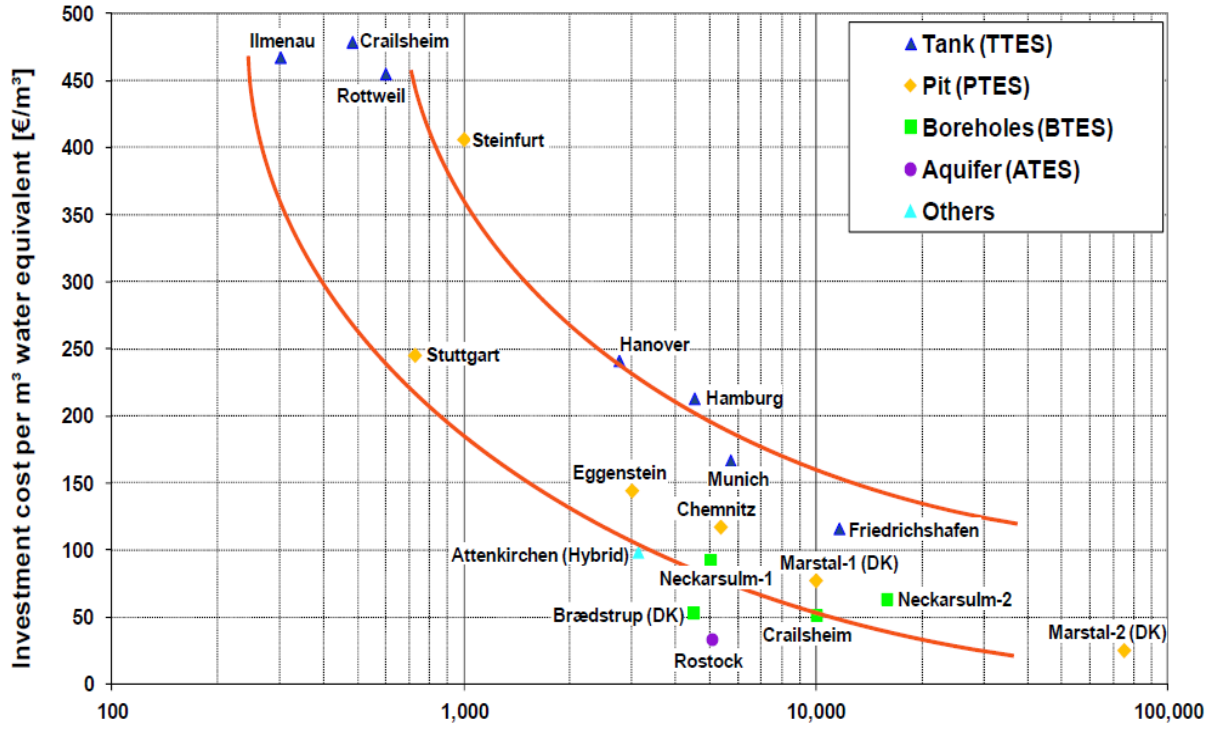


Figure 7.7 – Investment cost per m3 water equivalent of seasonal thermal storages that have been built in the last years (Source: Solites)

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Dynamic simulation:

Both the static and the dynamic energy simulation have been implemented to improve the balancing between the RES (Renewable Energy Sources), the TES (Thermal Energy Storage) to meet the energy requirement of the flats.

In June 2017 the new ISO 52016 was published, which profoundly changes the method for calculating the energy performance of the building previously based on the UNI TS 11300 static approach.

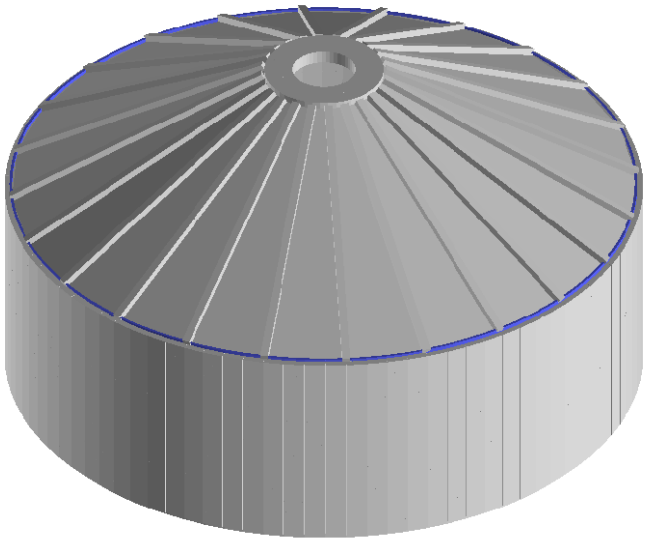
Compared to the classical static evaluation, the main advantage of the dynamic method is to bring the theoretical calculation closer to reality and obtain a prediction of the behaviour of the building-system that is more and more faithful to the real behaviour of the building.

In order to achieve this advantage, it is necessary to have an efficient model which has been developed in this case by UNIFI.

Through TRNSYS all components of the thermal plant have been modelled. The model is able to predict some important variables (the amount of annual energy consumption of the apartments, the hourly energy demand during a year of reference, the optimum size of the components, the expected energy balance at the end of the year of reference) starting from some input data, like user heat demand and weather data.

Shape:

Because of the limits imposed by the location and its characteristics (flooding risks, under waters, landscape preservation and consequent underground construction, disposal costs of excavation soils,…), different configurations and shapes have been analysed. A characteristic figure for the ratio of the heat losses to the amount of stored energy is the surface/volume ratio of the storage, therefore it's not convenient use more tanks for the same volume.



Related to the shape, the surface has been calculated in different volume hypothesis, in order to minimise the heat loss/costs and maximise the energy provided.

The capacity (volume, energy) has been developed to comply with the following standards / parameters / guidelines:

- replicability and economic sustainability, taking into account the costs of implementation and the various possible geometries (parallelepiped, cylindrical, etc.);
- analysis of the internal temperature of the stored water, considering:
  - the chemical and physical characteristics;
  - the temperature variation in correspondence of the decreasing depth;
  - the heat stratification;

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

- achieve to balance of solar energy absorption with the Storage capacity, aiming the target of the renewable energy percentage.

To avoid additional costs, due to specific earth support works and to operate safely during the excavation, the plant size presented a limit due to the distance between the buildings.

Materials:

The assumed material of construction is a waterproof concrete system which is impermeable to water and radon, providing a barrier which is the same thickness as the structure.

Cracking is an inevitable aspect of concrete during the curing process, the waterproof concrete mix design manages and controls this, combined with crack inducers helps avoid random cracks.

The structural analysis had to pay particular attention to the following loads:

- hydrostatic pressure,
- the variation of thermal loads according to the stratified hot water in the Tank,
- the seismic action

The storage is supposed to be heat insulated at the side walls, on the top and the bottom by foam glass with a minimum thickness of 70/80 cm.

As a waterproofing system, the "white tank" type system is envisaged with the addition of ulterior thermal joints specifically designed to withstand temperatures expected, in order to reduce the self-stresses of the concrete and get reduced cracking to make the container impermeable. In order to limit the cracking level of the concrete during the high temperature ranges, "rings" have also been provided in metallic carpentry along the height of the cylindrical portion of the storage.

The container consists of a tank of about 24m in diameter for a height of about 12.5m, of which 7.50m the cylindrical portion to which the conical portion is added.

Inside there are some pillars for the support of the roofing slab, the walls have a thickness of about 50cm and the foundation is in the stalls, also with a thickness of 50cm.

The excavation can be carried out without the need for supporting works on the ground, as the layout of the pool has been designed to be able to carry out the embankment easily.

The height of the tank has been dimensioned in such a way that, even considering the last excavation necessary for the construction of the insulating layer under the floor, the aquifer is not intercepted; this also in order not to contaminate it with the eventual dispersion of the heat.

Given the considerable thermal variations to which it is subjected and the hydraulic thrust which has a height of about 11.00 m, in order to contain the cracking state of the concrete, it has been established to rim the tank with metallic carpentry profiles

Solar panels:

To ensure the energy percentage from renewable sources target, various types of solar panels have been evaluated in detail, in relation to the characteristics of the building's roofs (surfaces, type of structures, loads, piping paths), the inclusion in the heating system (DH and storage), etc.

Flat plate collectors (FPC) are characterized by low cost but they have poor efficiency at high temperature (70-80°C). Since the implementation is dealing with a high temperature heating system (65°C), there is the need to completely charge the storage (up to 95°C) and for this reason FPC are not suitable. Parabolic trough collectors (PTC) have high efficiency at high temperature but they are expensive, and they are not suitable to be installed on a roof (dimensions, wind loads,..). Small PTC appropriate for roof have been developed but not beet yet certificated.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

The best compromise resulted the evacuated tubular collectors (ETC) with compound parabolic collector because they possess high efficiency at high temperature, medium cost, and they are a mature technology. For that reasons, this kind of solar collector has been selected.

Innovation level:

The ranking list of European solar heating plants developed by IEE SDH project (http://solar-district-heating.eu) reports only 14 similar plants for technology and size, located in the northern part of EU (Denmark and Sweden mainly, some examples in Germany and Switzerland).

No examples in Italy (only feasibility studies or solar plants directly connected to DH without any storage).

Main impacts of the measure (economical, environmental, social)

Direct impacts

After retrofitting, it is expected to achieve a reduction of the thermal demand of the buildings by a 35% through the improvement in the thermal properties of the envelope (insulation, elimination of thermal bridges, windows) along with optimized control strategies that will be implemented along with the renovated heating distribution system. Thanks to the solar production, the primary energy demand from fossil fuels will decrease of (by) the 50%. Tenants will save about 5-10% of their actual bills (considering consumption and private boilers maintenance costs)

Indirect impacts

The benefits of retrofitting are multiplied by the DH measure: the resulting system will be a unique implementation at national level with high performances in terms of energy and emission savings in an urban context; this pilot actions could represent a best practice to be replicated by ESCOs at metropolitan level and in the whole nation

Market analysis: enablers and obstacles

Competitors

Autonomous gas boilers or HPs, centralised gas boilers, biomass plants

Legal framework & incentives:

For new buildings there are national regulations for mandatory central heating systems and percentages of RES. This implementation could represent a solution also for new buildings (maybe with existing refurbished blocks connected to the same DH). Other regulations which affect the design phase are related to excavated soil and aquifer layers. Since 2016 there have been national incentives for buildings insulation, solar thermal plats, heat pumps and regulation&control systems. The incentives are paid at the end of the works and there are minimum requirements for the performances which must be better than the normal practice

Human factor (success factors, opposed sentiments,…)

The main success factors consist in small savings (-5/-10%) on the actual energy costs, less responsibilities (no more private boilers) for tenants and RES implementation with consequent GHG reduction. On the other hand, the complexity of the implementation and the absence of national examples are big obstacles for promoters and designers (need of capacity building); moreover the

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

costs are still very high even counting on the subsidies which are paid only at the end of the realisation (more chances for the ESCOs). The storage size and not optimal shape could be a limit due of space problems, related to flooding risk (the area has flooding risk because of the river Arno and therefore no significant additional volume has to be occupied by new constructions), to the presence of aquifer (the level of floating ground water is at circa 10mt under ground level) and increase of the costs also related to the newly published regulation about excavated soils; in addition the inadequate supporting roof structures of existing buildings need additional controls and reinforcing elements to carry the extra-loads due to solar panels.

First scale up analysis

Lessons learnt:

Regarding the storage, a sensible cost reduction could be obtained by using prefabricated elements, but being its calculation strictly bounded to the producer, in order to launching a public tender this solution is not available in this phase.

In order to reduce as much as possible, the volume of new technical rooms, part of plants and equipment has to be placed in the basement of existing buildings, increasing development costs.

A site with less boundaries could result cheaper allowing the construction of new volumes (not underground) both for the storage and the technical rooms.

A dynamic simulation could be a very useful support to the design phase in order to select the proper size of the storage, optimizing RES coverage and costs.

Capacity building is needed for designers and plant managers as far as there are no national examples already in place.

Optimal scale for next implementations

The optimal conditions for a solar thermal storage implementation are

- new buildings/districts
- old buildings with centralised heating plants
- existing district heating

In any case there should be room (preferably above ground) to host the storage volumes.

Further developments needed:

In advanced economies, a limit to the TES development is represented by the low rate of construction of new buildings, while in emerging countries the TES have a wider dissemination potential. For this purpose, it is very important to try to develop, test and optimize economically sustainable TES while retrofitting existing complexes. A key role is played by supporting research and development (R & D) of new materials, as well as policy measures and incentives.

Expected impacts:

The replication of thermal energy storages of any size could support the exploitation of solar energy in urban context, contributing to GHG and other local pollutants savings due to building sector in critical environments.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Solution 4: Energy Demand Management

Main partners involved: Tecnalia, Fomento de San Sebastian

General description

San Sebastian's Demand Side Platform, developed by Tecnalia, will allow residents to monitor how they are using their heating and to understand better how savings can be achieved. This platform will be integrated into the general DSM platform.
The District Heating generation plant, as described in the dedicated paragraph, consists of a 1400kW two biomass boilers as main heating supply and a 2300kW two gas boilers as backup and to cover peak loads. It is expected a reduction of 35% in primary energy consumption, being over 90% of this energy renewable (biomass). The District Heating system will give service to more than 1.500 new properties and 156 existing dwellings which are to be retrofitted
Thermal energy consumption will be monitored for each of the nearby new 1.500 households and 156 retrofitted households, fed by the DHS. As many as 22 additional thermal energy meters will as well be installed at different locations around the generation and the sub central plants.
Each user will be able to access to his or her actual or historic data about power and energy consumption, water flow and inlet and outlet temperatures, etc.
An Energy Management System (EMS) is planned to be designed to process all this information. This "black box" tool is based on historic data, and, using data analytics techniques, it is able to forecast the energy demands and to suggest energy saving measures.

Value proposition

Black box based EMS is meant to be the convenient tool for energy consumption forecast, minimizing the number of necessary sensors and optimizing the adaptability to new buildings and scenarios.
Using machine learning techniques and algorithms, the forecast of future energy demands can be dynamically adjusted and improved with new available data.

Technology

The solution in use

Physical based models try to establish all the physical equations which characterize thermal dynamics and energy behaviour, as a function of parameters and a set of multiple related variables. These kinds of models assume that the thermal characteristic of the building is known a priori. One of their major drawbacks is that this knowledge is difficult to obtain and very uncertain, not only for the simulation of individual elements, but for their relationships that will be reflected in big uncertainties in the simulated magnitudes.

Black box models are one way to overcome these inconveniencies. Regression machine learning techniques are based on monitored data, inferring nonlinear relationship of multiple non related magnitudes with one or several independent outputs. At a first stage, the regression algorithms need to learn from a training data set (historical monitored data set). This initial data set must be

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

representative of the processes to be modelled and, sometimes, experimental processes to generate data are needed. During this training process some internal parameters of the learner (regression scheme) are evolved and adjusted until the causality between inputs and outputs is inferred. Once completed this task, the adjusted model is tested with new input values.

One main drawback of this approximation is that regression techniques cannot learn any situation that has not been observed during the training process. On the other hand, sometimes, monitoring of all process-related magnitudes is a difficult task, limiting the performance of this kind of techniques.

Model Predictive Control (MPC) strategies receive all operating magnitudes to simulate the future thermal response of the building for a given time horizon (i. e. future conditions) and, thus, they can anticipate the heat supply depending on the prediction of room and supply temperatures. Their main objective is to minimize energy consumption while maintaining comfort restrictions, according to future weather conditions and building use. For this purpose, MPC takes into consideration comfort restrictions, weather forecast and historical data, updating decisions as new data become available.

In order to access to the Building Management Systems (BMS) data, a gateway is foreseen to be installed. Its Functional module, composed by a set of bundles and a data repository, would gather data from field devices and store values locally, in order to prevent data losses due to communication issues.

The Data Exchange module enables the communication with the Optimization server. This is composed, as the gateway node, of a Data Exchange module, and several functional modules: the Storage Engine, providing the data repository and data analytics functionalities; and the Optimization module, which evaluates the optimization scenarios and releases forecasts and operation schedules.

Innovation level:

Regression machine learning techniques and black box models constitute State of the Art highly innovative techniques. Based on big data processing algorithms, they allow to decouple from the physical grounds and to come up with operation decisions that can be dynamically and continuously improved.

Main impacts of the measure (economical, environmental, social)

Direct impacts

Boosting users' awareness on energy consumption and potential savings will reduce their energy bill and, at the end of the day, local and global energy production.

Indirect impacts

In general, improving consumers' awareness on energy consumption allows new energy and smart grid services to arise and be profitable, which could also benefit people awareness about other sustainable fields. Energy Services Enterprises (ESE) and other stakeholders related to the Energy sector could do business in a new, more competitive market. On the other hand, this will help

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

increase Renewable Energy Resources (RES) penetration rate, reducing carbon emissions. This is directly linked to creation of new jobs.

Market analysis: enablers and obstacles

Competitors

Though Building Management Systems (BMS) are manufactured and supplied by many companies, smart EMS are still in a low TRL. This is mainly due to a limited market that is growing due to environmental reasons and the corresponding regulatory support. Thus, little competition exists.

Legal framework & incentives:

Incentives and support from the legal framework are related to contribution to decrease of energy consumption, increase of RES penetration and improvement of energy efficiency. Those are conditions that EMS performance allows to achieve.

Human factor (success factors, opposed sentiments,…)

Customers' motivation to participate in demand response activities to help reduce energy consumption, e.g. through gamification, is the key factor for these benefits to become real.

First scale up analysis

Lessons learnt

At this moment no result has been monitored yet.

Optimal scale for next implementations

The first implementation stage is still to be carried out and experienced.

Further developments needed

The first implementation stage is still to be carried out and experienced.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Solution 5: EDMS connecting Smart homes & smart mobility

Main partners involved: Bristol City Council, NEC, Route Monkey, University of West England

General description

An Energy Demand Management System (EDMS), which connects with Smart Home and Smart Mobility devices using a newly developed Smart City Platform, has been developed.

The general functionality of the EDMS is monitoring and control of energy consumption and production. The EDMS accesses data from a wide range of equipment for generation, transport and consumption of energy, shows the gathered data in an intuitive way and make predictions and recommendations based on the observations.

The EDMS also acts as a marketplace, where multiple stakeholders can create energy management programs, each having its own set of requirements for participation, its own visualisations, and its own business models including the incentives for participants. On the other side, consumers or producers can become participants of programs, benefitting from the incentives offered.

Using learning techniques and algorithms, the forecast of future energy demands can be dynamically adjusted and improved with new available data.

Value proposition

The EDMS, as a monitoring and control of energy consumption and production system, aims at influencing supply and demand patterns in order to satisfy defined technical or economic objectives, to maximise local usage of locally produced energy, to maximize monetary benefits, and minimize the environmental footprint.
The technologies developed are expected to bring together a wide range of diverse small energy users such that they can manage their energy use collectively and therefore benefit from the commercial benefits that are only currently available to large players.

Technology

The solution in use:

Consumers or prosumers who participate in such programs, can register their devices (i.e. smart meter, thermostat, smart pug, etc.) at the EDMS and manage the connectivity and other properties. Data exchange with external components is realised by the communication APIs. The communication with the FIWARE platform takes place via the NGSI interface of FIWARE. The FIWARE instance is used for retrieving data about consumers and prosumers connected to FIWARE, and control commands can be issued by a publish/subscribe mechanism. Furthermore, the EDMS also exports data to FIWARE for publishing as open data or other usages, using the same interface.
Bristol Is Open has provided the infrastructure platform onto which data is backhauled and stored.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Smart Connected Homes involved 150 homes in the project area receiving smart home equipment including smart appliances (provided by Samsung) and related home hub and monitoring devices. The smart homes send data back to the FIWARE instance via Loxone MiniServer connectivity and over a VPN linking individual users with the Smart City Platform. Individual machines record and report their energy use, and data is collated in the FIWARE backend.

The monitoring panel is the interactive component of the EDMS. It is designed as a versatile tool for freely configurable visualisations of the available data. Additionally, manual control of devices and managing EDM programs is supported.

As for mobility data, FIWARE IOT agents component have been deployed in order to allow data collection. EV charging points communicate with the existing "Charge Your Car" Charge Point Management System. This system then allows real time and historic data to be produced on charge point usage for a number of functions. The real time data is automated via an API call to send data to the Smart City Platform using its FIWARE functionality.

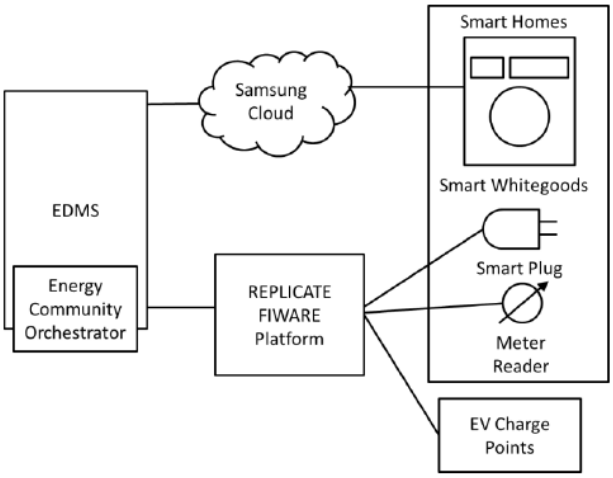


Figure 7.8 EDMS deployment

By acceding the EDMS monitoring, users can visualize static information about the smart homes connected in real team, but always protecting the privacy sensitive information. It is possible to see all available devices in one particular home and an historical graph of connected appliances consumption is shown.

In developing a theoretical model of energy consumption, it was taken in consideration that load curves of private households do not follow an easily predictable daily pattern and it is not practical to require a guaranteed level of demand elasticity from private households.

A Reinforcement Learning approach using a Combinatorial Multi-Bandit Problem has been developed. In it, when an actor takes an action, the result can be observed as the state of its environment, but it is initially unknown how each action influences the environment. The objective is to maximize the total expected reward, which is the combination of outcomes of the individual actors by a known reward function.

A Demand Side Response (DSR) trial is currently in design phase to roll out to a sample of the Smart Connected Homes. The aim of the trial is to co-design a consumer-acceptable DSR programme, engage and recruit households to participate and, alongside this, deliver an ICT package of works

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

that enables the technical delivery including linking control systems through the Smart City Platform and EDMS

As for the EV charging points, they have been successfully connected to the EDMS via the SCP. This was done using the Open Charge Point Protocol and FIWARE.

Innovation:

It has been established connectivity between IOT devices such as smart appliances, electric car charging points and smart meters in order to monitor and control energy demand within the city with highly innovative techniques

More specifically, thanks to the deployment of an Energy Demand Management System it is possible to monitor, through a FIWARE based Smart City Platform, the energy consumption of the connected devices in real time and remotely control domestic appliances by integrating with the smart appliance supplier's proprietary systems.

NEC has also developed an innovative and highly sophisticated approach to modelling the behaviour of a large number of independent energy consumers using the Combinatorial Multi-Bandit approach to seek to demonstrate theoretically that it is possible to optimise energy use across a range of actors. This approach has been designed to be highly transferrable to different problems and does not depend on extensive knowledge of the system or actors.

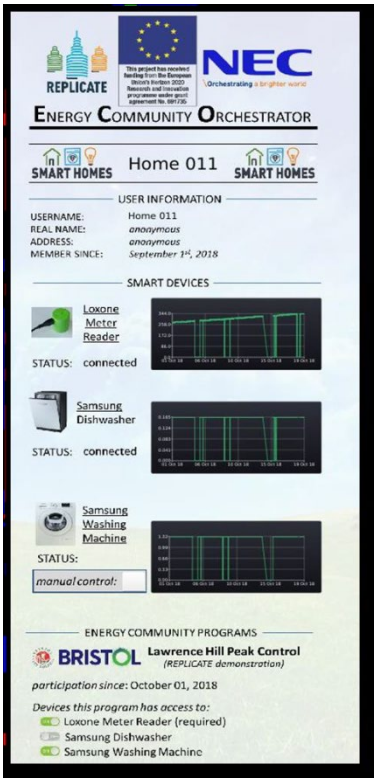


Figure 7.9 EDMS Monitoring

Main impacts

Direct impacts

Thanks to the EDMS it is expected that consumers become more rational energy users, which means a reduced environmental impact, improvement in air quality and lower energy demand pikes.

Moreover the EDMS envisages the consumer could offer to make unconditional load reductions, curtail their load or shift their load. All of these could result in cheaper energy (or other benefits).

Lastly, there is substantial potential through smarter charging to shift EV charging into periods when the energy mix is greener leading to significant environmental benefits.

Indirect impacts

The deployment of the EDMS can increase digital inclusion and reduce fuel poverty.

In general, improving consumers' awareness on energy consumption allows new energy and smart grid services to arise and be profitable, which could also benefit people awareness about other sustainable fields. Energy Services Companies and other stakeholders related to the Energy sector could do business in a new, more competitive market. This is directly linked to creation of new jobs.

Market analysis: enablers and obstacles

legal framework

Two main kind of contracts have been defined:

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

- Contracts for delivery partners to install and maintenance/service
- Contract between BCC and homeowner to take part in trial but no obligation afterwards. Homeowner free to keep appliance.

Terms and Conditions of working with each contract have been analysed in dept as compliance with GDPR.

incentives

No incentives are provided yet except the free use of the devices.
Demand Side Response (DSR) in the UK is currently limited to commercial premises primarily. There is no live marketplace for residential demand response. However in future with the UK's plan for a decentralised energy system, there will be an increasing role for residential level DSR as part of the smart grid.
In the next future they could be agreed with delivery partners or there could be some support from DNO/NG to help shift peak demand

human factor (success factors, opposed sentiments, …)

The rising costs of energy and the possibility of different tariffs could support the need of smart appliances in the near future as the availability of affordable smart appliances on the market.
The main obstacle to tackle is the digital inclusion and the fear of technology and data protection issues.

Competitors

Smart White Goods manufacturers.
Domestic electricity storage might negate part of the need for smart appliances – if batteries were distributed on mass in the future then there would be less of a need for timing energy use.

First findings and scale up analysis

Lessons learnt

For the development of the EDMS theoretical model, an algorithmic framework which requires minimal assumptions and minimal prior knowledge on the consumer behaviour had to be adopted due to the unpredictable daily partner that load curves of private households follow.
Thanks to the use of the Loxone MiniServer it is possible to drill down into the data to attribute it to individual devices rather than the whole property as would happen with just a smart meter.
The Charge Point Management System has been the weak link in the chain in terms of functionality. Close attention is needed when using open protocols so to ensure that the charge points and back office system provide compatible levels of smart grid functionality.

Optimal scale for next implementations

The NEC EDMS has been deployed trying to guarantee high flexibility which means that, with some customisation, it can be applied to a wide range of energy demand management situations. In fact, given that EDMSs will often need to interact with proprietary third party systems in order to be able to control devices remotely, it is unlikely that FIWARE will always be the whole solution, and so flexibility is important such that as wide a range of devices as possible can be incorporated.
On the EV side, the use of an open protocol such as the Open Charge Point Protocol will allow more flexibility and innovation in the future.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

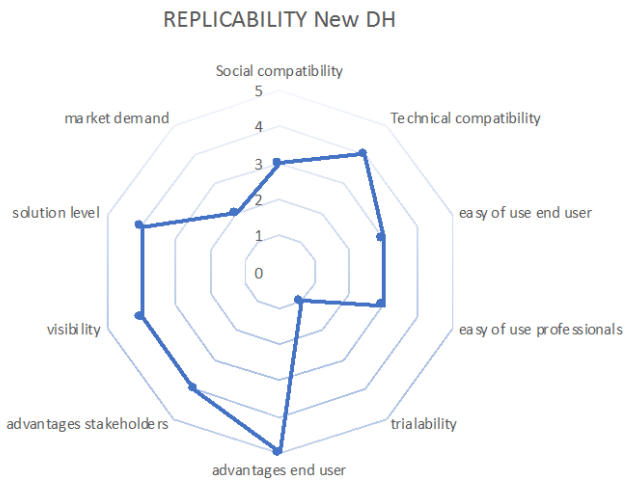
Expected impacts

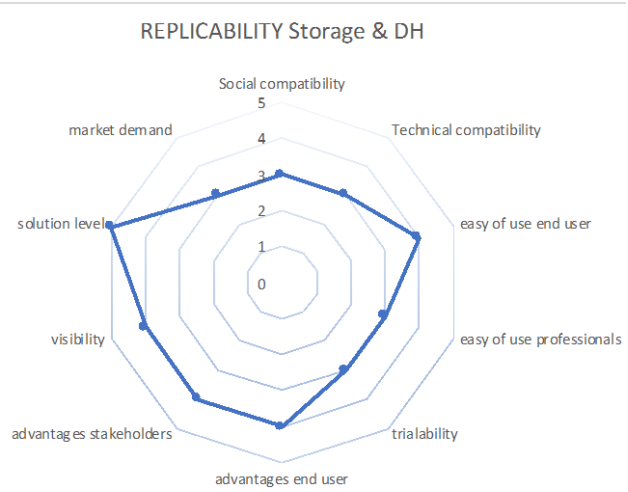
The REPLICATE EDMS trial and the DSR trial will provide clear evidence of the potential economic benefits that such systems could offer to consumers who are willing to offer flexibility.
Companies who control large EV fleets would be expected to be able to offer quite large potential energy shifts which would be expected to become commercially viable providing the regulatory frameworks and the technologies, such as the EDMS, allow the right level of granularity and trust such that aggregators can be confident about the savings they can offer and a value that can be placed on these.

Comparison of the different solutions and approaches

District heating systems

The three district heating systems are quite innovative for the national situations and they have been tailored on the specific needs of the territory: in San Sebastian and Florence new systems have been built exploiting the available RES (biomass from the Basque country and solar energy in Florence urban context), while in Bristol the already existing DH has been revamped and updated with the use of RES to allow new connections.
Despite they all present high advantages for end users and good solution levels (targeting common issues for smart cities), their social compatibility is an aspect to improve for the replicability and scale up with information and education campaigns. The trialability (small scale testing) is something that doesn't fit to that kind of solutions which can hardly find a chance to be experimented within the local context before full implementation; a test represents less uncertainty for the potential adopter and it allows for further fine-tuning of a solution itself to increase its performance. The pilot actions are precisely meant to be the test bed for a scale up at local level, even if the market demand in medium-sized cities is not very high, and mostly for a replication in their regional/national context.





This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

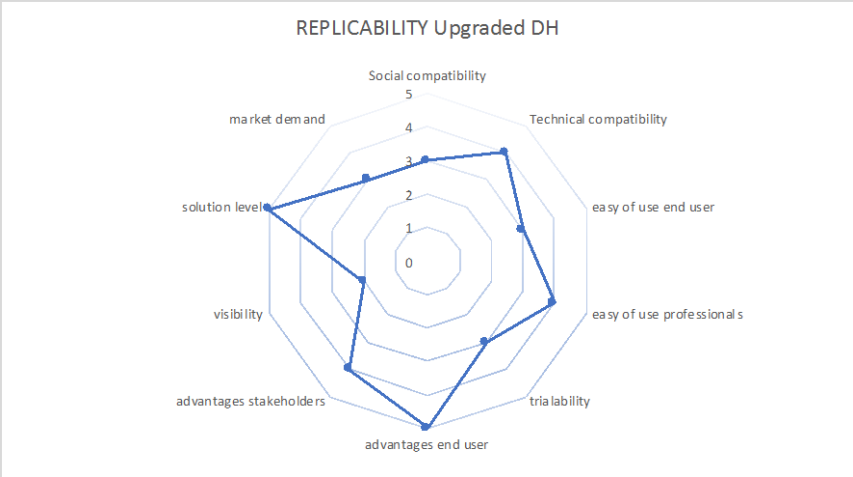


Figure 7.10 comparison among the replicability of the different solutions about DH

EDMS

The approach of the two systems illustrated is similar and aimed at rising awareness among consumers. In the first case it has been developed together with the retrofitting & DH measures to control the energy consumption of the refurbished buildings linked to the Building Management Systems, while in the second case, thanks to the support producers, it is more focused on smart devices management extended from homes to mobility.

The two solutions present a similar result in terms of scalability with high technical compatibility (one of the main features) and they represent good answers to cities and markets requests. The user-friendliness of both the systems ought to be further optimized to become more and more popular among users and professionals.

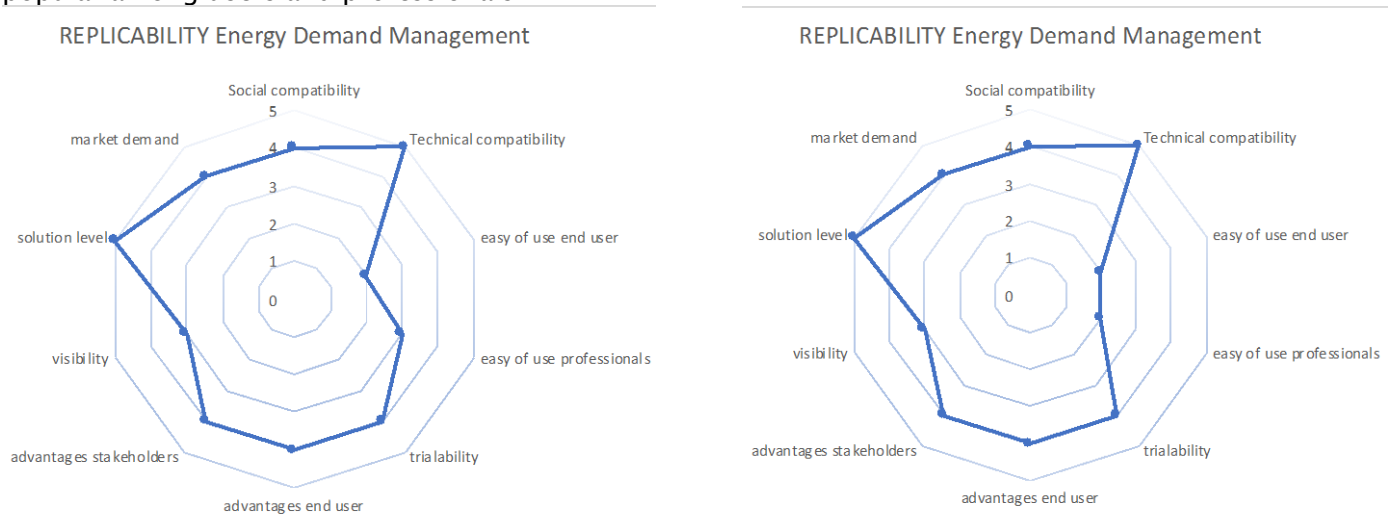


Figure 7.11 comparison among the different solutions about energy demand management

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

8. Smart mobility and related services

In this section the introduction of e-fleets (e-taxis and e-bikes) and charging infrastructures (fast for reserved fleets and public) is illustrated together with the innovative systems developed for efficient parking and multimodality.

Solution 1: e-taxi fleet and fast recharging infrastructure

Main partners involved: City of Florence, e-distribuzione, Mathema; CNR, UNIFI and SPES are also involved.

Short description of the action

The action consists in enhancing the switch to electric vehicles of the taxi public service both to increase its sustainability and to promote the electric mobility to city users. The partners involved are the municipality of Florence, e-distribuzione (local DSO) and Mathema. Municipality of Florence regulates the public service, defined the site position of the Fast Recharge Plus of the project creating exclusive areas for new e-taxis recharge. E-distribuzione has selected the technology and is in charge of the management for the project lifetime, Mathema has developed the App for taxi drivers.

The municipality published a dedicated tender exclusively for e-taxi service (70 new licenses dedicated to e-vehicles) with a 25% discount and provided agreements with vehicles producers for special purchasing conditions.
In parallel e-distribuzione installed six new Enel Fast Recharge Plus 1G (EFRP) charging stations, for exclusive use of taxi in public areas identified together with the Municipality and with the taxi drivers' association.
The stations have been installed in crucial points of the city (near the main station, the airport and the entrances).
The EFRP charging stations are fully integrated in the LV distribution network in a "smart way", ensuring the security and the stability of electric system, with the possibility to modulate the current of each charging, thanks to the remotely control of Electric Mobility Management (EMM) Platform.
Through the EMM Platform, all charging stations are managed in an interoperable way, non-discriminatory access and multi-vendor approach, thanks to the smart meter technology, thus assuring benefits to the end-user guaranteed by free market competition.
The full integration of the EVSEs in the low voltage distribution network and the management based on the EMM Platform provide the possibility to manage in a better way energy flows avoiding networks overloads on one hand and, and enabling new customer experiences based on innovative services and solutions in other hand, such as:
- the possibility to identify the closest fast charging point and reserve it through mobile phone (Mathema's app available for taxi drivers);
- monitoring and controlling of charging process;
- load modulation; payment of charging directly in the bill, according to the tariff profiles signed with your retailer.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

This will foster the development of electric mobility without compromising the safety of systems and the quality of supplying for other customers.

Value proposition

In Florence the transport sector has the largest impact, with 0.88 Mt/year of CO_2 emitted, 34.5% of the total. What is required is a substantial, integrated action which makes it possible – even in a difficult situation such as that of urban Florence, congested as it is by commuter and tourist flows – to achieve a significant reduction in the environmental impact of mobility in the context of the city.
The municipality is promoting sustainable mobility and in particular e-mobility starting from the public tramlines, its own fleet, the e-sharing service, the incentives (LTZ access, public recharging network, free parking,...)
Taxi fleet presents particular needs in terms of autonomy and charging periods while is a powerful dissemination channel for e-mobility to city users.
170 public electric recharging infrastructures are already available, remotely managed and included in the open data webpage of the municipality.

Technology

The solution in use: the e- vehicle and the service

The tender of the municipality was exclusive for vehicles called "plug-ins", the only ones that allow the recharge of the storage system inside the vehicle directly from the electricity grid, and in particular for the Battery-Electric Vehicle BEV (the other types on the market are Plug-In Hybrid Electric Vehicle PHEV and Extended Range Electric Vehicle REEV or E-REV equipped with an additional engine powered by petrol or diesel).
The economic requirements highlighted in the tendering procedure consisted in a fee of 175.000€ for each licence, a lower value compared to the 250.000€ asked previously to the traditional taxis, because the municipality decided to decrease the amount of the 30% due to the higher costs for the e-vehicle purchase and maintenance.
Therefore since the beginning an economical discount has been foreseen to promote electric mobility together with new jobs to fight unemployment and to enhance economic growth in the city.
The service has been significantly optimised: in the rush hours there are going to be 50 more vehicles at the train station or at the airport while from 11am to 23pm there will be about 15-20 (with 4 e-taxi), between 13am-1pm the number will be increased from 90 to 110 (with 10 e-taxis), in the slots 7am-13pm and 17pm-23pm there will be the highest increase from 25 to 85 (with 32 e-taxis) and finally from 9am to 21 pm the available taxi vehicles will be 55 instead of 40 with 5 new e-licences.
The winners of the tender had 30 days to purchase the e-vehicles and to proceed with the formalization of the business and to withdraw the license, providing the insurance of payment required.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

The vehicles purchased by the taxi drivers are mainly Nissan (Leaf models with power 80kW, battery 30 kWh, 250km) but also Hyundai and Renault. From a first survey the choice takes into account the volumes needed for such a service, the cost (considering the favourable offers of project supporters) and the autonomy.

The recharging infrastructure:

The two main alternatives for charging from a column are those in direct current (DC) and in alternating current (AC). Four different charging methods are identified, as provided for by the IEC 61851-1 standard (Electric vehicle conductive charging system, which came into force in 2010), which vary according to:

- the type of current (which can be continuous, alternating single-phase or alternating three-phase);
- the voltage;
- the presence or absence of earthing and control lines to enable a mono or bi-directional dialogue between the vehicle and the charging station;
- presence and relative location of a safety device.

For alternating current charging mode, which is currently the most common mode, there are three alternatives (so-called Mode 1 for domestic and light vehicles usage, Mode 2 for domestic or industrial implementations with slow recharges and Mode 3 also for fast recharges and open public spaces). For the mode of direct current charging there is a single alternative, so-called Mode 4.
Regarding the power outlets, in the standard IEC 62196-2 (Plugs, socket-outlets, vehicle couplers and vehicle inlets - published in 2011 and updated in 2016) there are three types of connectors for vehicle charging electric: Type 1, Type 2 and Type 3 (further divided into type 3A and type 3C). These connectors are used to charge vehicles in Mode 2 and Mode 3. For Mode 4 there are two official connectors, called CHAdeMO (Nissan, Mitsubishi, Toyota, Citroen,...) and CCS Combo (BMW, Volkswagen,..).
The European Commission has identified in Directive 2014/94 / EU, the Directive Alternative Fuel Initiative (DAFI), 3 types of connectors depending on the power and the mode of supply of the refill. These guidelines have been adopted in the PNIRE (National Infrastructural Plan for the Recharge of Vehicles powered by Electric Power) which foresees 3 charging standards for public recharging networks.

Mode	Speed	Connection
Mode 3	Normal power High power	Type 2
Mode 4	High power	• Combo CCS • CHAdeMO (*)
(*) *The CHAdeMO connector will be a standard admitted to 31 December 2018. Within this deadline, all recharging points introduced or renewed must be equipped with a Combo CCS connector.*		

Figure 8.1 - PNIRE regulation for recharging in public areas

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Classification in use here	Level	Current	Power	Type			
				China	Europe	Japan	North America
	Level 1	AC	≤ 3.7 kW	Devices installed in private households, the primary purpose of which is not recharging electric vehicles			SAE J1772 Type 1
Slow chargers	Level 2	AC	> 3.7 kW and ≤ 22 kW	GB/T 20234 AC	IEC 62196 Type 2	SAE J1772 Type 1	SAE J1772 Type 1
	Level 2	AC	≤ 22 kW	Tesla connector			
Fast chargers	Level 3	AC, triphase	> 22 kW and ≤ 43.5 kW		IEC 62196 Type 2		SAE J3068 (under development)
	Level 3	DC	Currently < 200 kW	GB/T 20234 DC	CCS Combo 2 Connector (IEC 62196 Type 2 & DC)	CHAdeMO	CCS Combo 1 Connector (SAE J1772 Type 1 & DC)
	Level 3	DC	Currently < 150 kW	Tesla and CHAdeMO connectors			

Sources: IEA elaboration based on AFDC (2017), Bohn (2011), CHAdeMO (2012), CharIN (2017a), CharIN (2017b), EC (2014), Electric Vehicle Institute (2017), HK EMSD (2015) and State Grid Corporation of China (2013).

Key point: Various sockets and connectors are in use across the main global regions. Two main combined charging systems (CCSs) were recently developed to standardise the connections. They are the current standards adopted in Europe and the United States.

Figure 8.2 – Overview of the level (power output) and type (socket and connector) of EVSE used in China, Europe, Japan and the United States (IEA 2017)

The technology adopted in Florence by e-distribuzione, the Enel Fast Recharge Plus (EFRP) 1G, allows a DC charging up to 50 kW based either on the Chademo protocol or on DIN70121 protocol (Combo CCS), and two AC charging at 43 kW and 22 kW based on the IEC 62196 standard and IEC 61851 series (Type 2).

As the AC charging station, also the EFPR1G is equipped with Enel MID certified meter and 3G modem. The performance of the EFRP1G assure a power factor greater than 97% and an efficiency greater than 95%.

At the same time, it allows just one DC charging (the charging station is equipped with an AC/DC converter) and both AC charging station, so the maximum power required is 115 kW.

EFRP1G is remotely controlled real time by the EMM Platform, a remote central multitenant system, able to manage and control the charging and to manage the contract and the RFID. Thanks to this permanently connection with the EMM, on one side it is possible to modulate the power or to configure the EFRP with a power lower than the total required one, according to customers' needs, activating the smart charging algorithm, on the other side it is possible to enable just a part of the customers.

For the first point, the smart charging algorithm is automatically activated when the charging station is configured inside the EMM Platform with an availability of the power lower than the maximum required for each charging. In this condition, when DC and AC charging are contemporaneous, the power for the AC charging is decreased, promoting the DC charging, which usually lasts few minutes in comparison with the AC charging.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

The second point, it is one of the major topics for project. For the first 5 years, the Replicate project lifetime, from the installation date of the EFRP1G, just the e-taxi shall be able to charge from the EFRP1G. This is possible thanks to the EMM Platform, with whom the contract is managed, and configuring opportunely the charging station the charging session is activated just for those contracts.
This product guarantees a full interoperability with all EVs present in the market and reduces the charging time equivalent of a stop-coffee, significantly expanding the potential of use of electric vehicles.

The managing system EMM

The EMM Platform is a multitenant system designed for the Asset Provider (AP) and Service Provider (SP), with a dedicated part for the automatic billing and for the power grid control.
So starting from the configuration of each charging station inside the system, the AP can manage its infrastructure, checking the alarms and possible malfunctions, monitoring the charging session and modulating the power for each charging session.
Instead, the SP is the stakeholder that manage the contracts, the activation of the RFID linked to the contract, and possible service to the final customers. This is a key point in the project, since with a dedicated contract for each e-taxi, they will be the only customers able to charge at EFRP1G.
The structure of the EMM Platform allows an easy integration of the charging in the power network, taking into consideration the meter installed in each charging station.
To activate service from stakeholder external to the EMM Platform is necessary to connect with a web service for the dedicated service.

The app for the e-taxi drivers

Inside the project, four EFRP1G are installed in Florence, in addition to about 200 charging station already installed in the city thanks to other projects. The major part of those are owned by the municipality of Florence, always based on the Enel Technology. Since the system is the same, the compatibility is automatically assured and the entire public EV infrastructure is available, in the REPLICATE project, for the e-taxi. The private customers cannot charge at the EFRP1G for the first 5 years since the installation.
The existing infrastructure is built by:

- AC charging station type 2 – type 3a
- AC charging station type 3a – type 3a

The socket type 3a is typical for the light vehicle charging like the electric scooter, and type 2 is typical for the EV charging.
Inside the project, the collaboration with other partners assure:

- The total integration of all infrastructure inside a system of the municipality without the possibility of managing the charging station, but with the possibility of verifying the real status and charging session
- An app to book the EFRP1G by the e-taxi, without the possibility of booking of the public AC charging station.

Both communications are based on dedicated web service and so with a call to EMM Platform for the needed information.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Innovation level:

A full electric Taxi service with more than 70 e-cars and a dedicated fast recharging network provided with booking option hasn't been experienced yet at least at national level.
Before Replicate, in Italy only one pilot EFRP1G station had been built.

Main impacts of the measure (economical, environmental, social)

Direct impacts

During the project lifetime at least 100 e-taxis will start the service with a yearly average consumption savings of 225.000 fuel litres which means -200 CO_2t/y

Indirect impacts

e-vehicles supply chain boost, users' sensitization

Market analysis: enablers and obstacles

Competitors

In general, the main competitors to fully electric cars are hybrid vehicles and traditional fuelled vehicles.

Legal framework & incentives

There are different kind of incentives available for e-mobility.
At national level, as reported in the framework paragraph, the national plan for e-mobility supports the development of a widespread and performing infrastructure for the recharge. (E-distribuzione as DSO has no facilitations or economic incentives on this technology).
National incentives with an economic value:
- 50% reduction on the cost of insurance, considered by the consumers the heaviest burden to sustain;
- Exemption from payment of vehicle taxes for five years from the date of the first registration.

At local level many supporting measures have been made available to concretise the municipal plan for e-mobility development and the smart city plan measures about e-mobility and eco road pricing
Local facilitations have been more focused on the topic of circulation:
- Presence of a capillary infrastructural network of public charging stations;
- bonus Recharge for existing taxi licences switched into e-taxis
- Freedom of movement of electric vehicles in restricted traffic zones;
- prioritization of the green e-taxi service
- First 80 licences discount (-30%)
- app for fast recharge booking and real time mapping of the public network

Human factor (success factors, opposed sentiments,…)

The main obstacle from the taxi drivers' point of view is the high investment for the e-vehicle and the battery performances.
Counting on a widespread public charging network and a dedicated fast network (and the possibility of charging at home), the autonomy of the batteries seems not to affect the choice.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

The multivendor opportunity offered by the charging network is very important from the users' point of view.
The app and the possible prioritization of the greener e-service have been discussed and agreed with the association; the key factor for replicability and the deployment, is the decreasing in fast recharging infrastructure and e-vehicles costs.

First scale up analysis

Lessons learnt

The collection of all the competent bodies opinions for the installation of the fast recharge stations has taken more time than expected, because of the bindings of Florence's cultural heritage and also of the new national rules on public tendering which are affecting all the phases of the tendering procedure (validation of the design at each stage with the public selection of the validator, most cost-efficient bid evaluation with a technical judging board, cash flow for the tendering procedure, lower possibility of "testing" solutions outside the market,…).
The electric vehicles technology and the recharging procedure need a bit of training before the daily use.
Some exchanging protocols between the fast recharging station and the different car models have to be tuned to work properly.
There is a need of surveillance for the recharging infrastructure in some areas due to vandalism problems and to avoid unwanted parking.
The energy tariffs for e-mobility are very different in the market and should be analysed in detail to find the best option for the different users.

Optimal scale for next implementations

The test could be easily extended at metropolitan level and to other large private fleets (as foreseen in the national plan PNIRE), or replicated on the main highways (Enel EVA+ project)

Further developments needed

Any developments will be related to technological developments and standardization of technology and protocols

Expected impacts

The path foreseen by Florence municipality through the modernization and sustainability of the public taxi service is very ambitious: the fleet should become soon made of hybrid and electric vehicles.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Solution 2: Charging points

Main partners involved: Bristol City Council (The Go Ultra Low West – GULW – program, a partnership between the four West of England Authorities of Bath and North East Somerset, Bristol, North Somerset and South Gloucestershire Councils).

Short description of the action

The REPLICATE Bristol Mobility Actions have adapted transport infrastructure relating to EV charge point Installation. This has covered the data requirements of connecting users to new EV infrastructure, the installation of new charge points, and integration with vehicles, back offices and data platforms. As part of REPLICATE and the Go Ultra Low (UK government programme) projects Bristol has installed the first three EV charge points for car club vehicles.
Bristol City Council will make use of 12 on street charge points and 12 off street charge points funded by Go Ultra Low.
Bristol City Council's Energy Service is overseeing the roll out of EV charge points in partnership with Bristol City Council's highway team. The assets will become BCC infrastructure and be managed accordingly. BCC Energy Service also manages BCC's energy contract.
As for the electric bicycle infrastructure, the e-bikes are being placed within public, private, voluntary and community organisations that are either based in or have staff that operate in the project area.
The bicycles are kept within the organisations and are charged by the user from a standard plug socket in their building, as required.
By using the FIWARE functionality, e-bikes have been connected to the Smart City Platform and expect to do so imminently with EV charge points.

Value proposition

The aim of the action is to promote the substitution of conventional fuel vehicles by Full Electrical Vehicles and improvement of the charging infrastructure. Furthermore the actions aim at developing innovative solutions within Smart Grid measures, that will make possible advanced functionalities for remote monitoring, control of equipment, advanced automation functionalities and Energy Demand Side Efficiency.

The main target is the reduction of the mobility impact, for both people and goods, in terms of energy consumption and CO_2 emissions, and the reduction of the average journey delay.

Technology

The solution in use:

The first step in the charge points project was to determine the suitable sites: the sites have to be situated over an existing service and proximity to power supply as the cost of trenching is expensive. The first three chosen sites are Brunswick Square, Counterslip and Stuart St. These were quite different locations with quite different likely usage patterns.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

22kW 3 phase AC charge points have been provided on the basis that these would provide the most future-proofing and provide the best fit with the car club model being trialled as part of REPLICATE. The choice has been guided by the requirements of the Open Charge Point Protocol (OCPP) – an application protocol for communication between EV charging stations and a central management system developed by the Open Charge Alliance (www.openchargealliance.org).
Its aim is to create an open application protocol which allows EV charging stations and central management systems from different vendors to communicate with each other.
EVs are booked in the same way as other cars. (i.e. start and finish time). Bristol's current car club model is that each vehicle returns to its own base upon completion of the hire.
Buzz services will be available via a mobile responsive web-interface and an app. The app will definitely be available in Android and in iOS before the project end. The app will allow users to create accounts or sign in using an existing Facebook account, plan journeys, purchase tickets, scan tickets when boarding and receive travel notifications.

Charge points will become part of the Charge Your Car network managed by Bristol City Council's Energy Service. The Co-wheels charge points will be standalone charge points not linked to the main network (i.e. the public will not be able to charge their own cars at these sites) as they must be available at all times for the Cowheels vehicles.
The first batch of charge points are produced by three different manufacturers (Chargemaster, APT and Alfen). All are either OCPP 1.5 or 1.6 compatible and so this defines the protocol with which they communicate with the back office.
The charge points communicate with the vehicles using industry standard protocols via the charging cable. The exact functionality depends on the charge point- vehicle combination. The charge points use 3G/4G M2M SIMs. This allows the charge point to identify authorised and unauthorised users which it can then use to only open the socket for recognised users. The charge points can then also communicate information on usage back to the back office for billing purposes.
The back-office system receives messages from the current set of charge points using M2M SIM from the charge points using OCPP protocols.
Charge Your Car is not directly part of the REPLICATE project so there has been very limited scope to reconfigure the back office to provide additional functionality. In the Things Network acts as an aggregator of data from the Internet of Things. It is based around LoRaWAN and it allows for things to pass messages to the internet without 3G or WiFi, meaning assets can be low battery usage, long range and low bandwidth. Currently the Things Network is used to backhaul data from the bicycles and not from the cars
Once collected the data, Route Monkey's optimisation engine will analyse as much data as possible relating to charge points in order to be able predict when demand will be high and when it will be low. This will help to inform when ideally an EV should charge, or when in future it could provide energy to the grid.
The EDMS will analyse data from the charge points via the Smart City (FIWARE) Platform.
The process of data acquisition and transformation is still being finalised; however it is intended to use the Open Data Portal and the Smart City Platform where it is possible to automate the data collation and transfer processes.

Innovation:

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Within the project framework, a large amount of data is integrated and transferred between users, vehicles, back offices and optimisation engines.
REPLICATE is providing smart real time reporting functionality for ebikes through a series of innovative additions to the Co-wheels ebike system. Thanks to technology deployed it is possible to integrate the system with the ebike CAN bus, with ebike power supply and that standards exist for the compressed transmission of many different types of data set, including GPS.
Lastly, thanks to the FIWARE functionality of the Smart City Platform it is possible to connect to ebikes and expect to do so imminently with EV charge points. The FIWARE protocol allows the Energy Demand Management System to communicate with the Smart City Platform.

Main impacts

Direct impacts:
Boost of sustainable mobility with consequent environmental benefits (less CO_2 emissions). Changing mobility behaviours.
Indirect impacts:
Increase in the use of RES for electricity production. Technology development and creation on new jobs.

Market analysis: enablers and obstacles

legal framework:
There is as yet not a standard nationwide framework for the process of installing charge points. There is currently a Bill going through the Houses of Parliament called the Automated and Electric Vehicles Bill 2017-19 which will seek to provide national standards for charge points (https://services.parliament.uk/bills/2017-19/automatedandelectricvehicles.html).
As for the power grid, in the UK the standard process for assessing what services are underground is called a NRSWA (New Roads & Streets Works Act). This is a standard process whereby all utility companies have to respond to a request for information about their services in a particular area.
incentives:
None
human factor (success factors, opposed sentiments, …):
The systems developed are easy to use by users. This has been achieved through using some existing and some new booking systems mainly based on mobile phones.
The main challenges are represented by the insufficient local knowledge and confidence in the system.
Pricing mechanisms is important to encourage users to modify their behaviour. The present charging systems where users pay per kWh do not encourage energy suppliers to discourage profligate energy usage or to avoid peak times.
Competitors:
Others EV charge points installers

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

First findings and scale up analysis

Lessons learnt:

- One of the biggest constraints on the roll out of on street charge points has been the UK's Traffic Regulation Order process. The move toward more intelligent vehicles is likely to increase the demand for standard Traffic regulation Order processes.
- Having standard data on underground utilities available early would avoid going down "blind alleys" with sites that are not viable and make the site selection process for efficient.
- The need for large electric meter boxes on narrow streets as well as charge points was a significant constraint. There are also significant opportunities from unmetered or "self-metered" (i.e. the user measure's their own energy consumption using certified meter equipment) as this would greatly simplify the on-street equipment that needs to be deployed.
- The back-office functionality is very important. Flexibility and APIs are keys. As we move from passive to active modes there will be a need for stronger security protocols.

Optimal scale for next implementations:

A grid impact study has been conducted in order to look at the theoretical implications of extending this approach at a larger scale. The grid impact assessment explored the impact on the distribution network of rolling out the sort of measures in REPLICATE on a wider scale and showed that the ability to respond to the state of the network will greatly reduce the impact of EVs on the distribution network.

The pricing mechanism should be changed to modify users' behaviours. A move towards "Energy as a Service" models in the e-mobility sector would be one of the models to incentivise more creative business models.

Coordination between actors in the EV space will be a key if the maximum benefits of emobility are to be achieved.

Expected impacts in the next future:

It is expected that the improvement of the EV charging points infrastructure will promote the gradual renewal of the private vehicle fleet. Alongside, it is important to introduce incentives for the EV diffusion. Given it is very likely that Distribution Network Operators and energy suppliers will increasingly incentivise users who can offer flexibility in order to reduce peak loads on the system there are likely to be increasingly strong incentives to develop these systems.

As for the demand management, in the longer term the aspiration must be that demand management controls go through a suitably upgraded back office. There is also more work to be done on linking systems to make the users experience seamless. There are opportunities to make the booking more sophisticated based on information about future journey length. In future there could be possibilities to incentivise certain behaviours or disincentive others according to the state of the distribution network or other parameters.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Solution 3: e-bikes

Main partners involved: Co-Wheels, Bristol City Council, University of Bristol, University of West England

Short description of the action

Implementation of 12 electric bikes in corporate, community and public sector settings in the project area. The bikes are housed and charged by the organisations. The bikes are serviced and maintained by Co-wheels. Each bike will have a bespoke tracking unit installed and managed by University of Bristol. The option also exists for the bikes to be integrated into Co-wheels online booking system. University of Bristol has developed a customised monitoring system for the e-bikes which includes a GPS system as well as access to the e-bike onboard diagnostics system which will allow a wide range of data to be analysed on bicycle usage.
The e-bikes trackers use WiFi and Bluetooth as well as a LoRaWAN interfaces. Special compression protocols were developed to ensure data can be transferred efficiently.

Value proposition

Enabling greater, sustainable and active mobility by:

- Increasing health & wellbeing
- Enabling better access to employment
- Reducing congestion and carbon emissions
- Breaking down barriers to active and sustainable travel

The e-bikes should also enable better access to clients in the course of work, with improvement in the way employees carry out their job.

Technology

The solution in use:

The e-bikes needed to be robust, easy to manage and suitable for a wide range of users.

Essential requirements included a step-through frame, integral hub gears, a pannier rack, fixed front and rear lights, a fixed handlebar mounted display, hydraulic disc or rim brakes and puncture resistant tyres. Due to Bristol being a very hilly city, as many different levels of electric assist as possible were also required.

The e-bike has an on-board control system, the components of which communicate via an internal network (a CAN bus, described below). By developing a number of prototypes to test that each element of the design is viable, a Mobility Monitoring System has been designed and manufactured that is able to 'sniff' this internal network and gain information about how the e-bike is used.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

The monitoring hardware uses a single board computer running a full Linux implementation. This provides much more functionality and flexibility and eases the deployment of new software, allowing a very wide range of applications to be developed for the platform.

The Monitoring System connects to the e-bike via two interfaces, namely the power, which it takes from the power supply designed for the e-bike display, and the CAN bus. CAN is a serial protocol standard used widely in automotive. The e-bike drive system comprises a number of different components (namely the display, electric drive and battery) and it is through the CAN bus that these communicate. They transfer a huge amount of information about the status of the e-bike and the actions of the user.
By listening to the CAN bus the Monitoring System can record information such as battery status, bike speed and level of electric assist. Alongside the CAN bus data, the monitoring hardware is also equipped with a GPS unit and accelerometers.
As well as WiFi and Bluetooth the hardware also has a LoRaWAN interface and this can be used to send short messages (<60 bytes due to limitations in the software) many kilometres.
When the monitoring hardware detects a WiFi access point is available it will connect to it, and at the of a journey will transfer all of the records it has directly up the central server.
The monitoring hardware has an internal battery that is charged while the e-bike is on. This allows the monitoring hardware to operate for around 20 minutes after the e-bike has been turned off.
Once on the e-bike monitoring server all data is passed to a message broker so that it can be processed and formatted ready for long term storage in a time series database.
The data is stored in a time series database, to which project partners will be granted access. The database implements a range of standard APIs, allowing researchers to efficiently access and process the data through a wide range of software options. Data can be selected for download based on a large number of criteria, meaning that researchers do not need to transfer very large files much of which is not relevant. The dashboard developed provides a powerful yet intuitive web front end through which researchers are able to explore and understand the data.

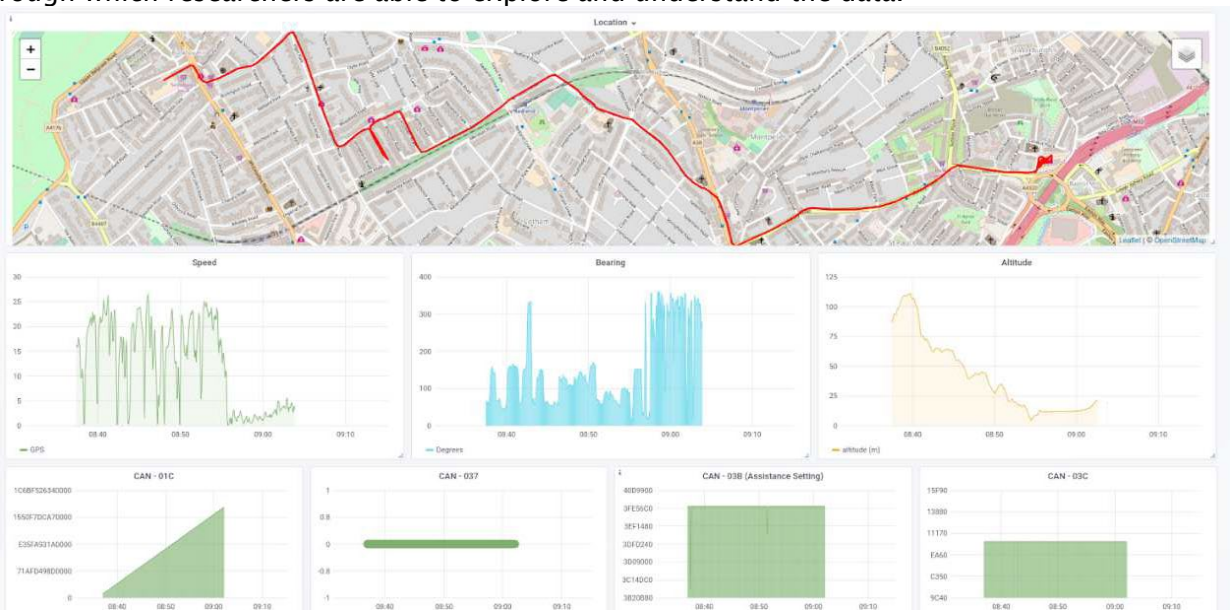


Figure 8.4 The Data Dashboard

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Innovation:

Co-wheels have integrated the e-bikes into their existing car club booking system. The implication of this is that it is possible for members to join the car club and gain access to both the e-bikes and the national network of Co-wheels vehicles.

The deployed e-bike monitoring system has a number of smart aspects including:

- using a single board computer running a full Linux implementation
- listening to the CAN bus to measure values such as bike speed
- the addition of a GPS unit and accelerometers to provide extensive details of e-bike use
- the combination of WiFi, Bluetooth and a LoRaWAN to make data transfer efficient
- development of the software to make the addition of new measurements very straight forward

Furthermore the use of Gecko solid rubber tyres has completely removed punctures as an issue.

On the manufacturing side, the modular design, use of COTS components, 3D printing and PCB layout files will ensure fast and efficient manufacture at significantly reduced cost.

Main impacts

Direct impacts:

The introduction of e-bikes can change transport behaviours of the involved individuals and organisations and promote the sustainable mobility. This results in fewer combustion engine vehicles in circulation and less traffic with benefits for the environment and for the liveability of the city. Additionally, the project improves the social inclusion as it allows the access to cars and e-bikes without the expense of ownership.

However, the provision of a sustainable and more affordable mode of transport for those employees who need to travel in the course of work is the most immediately known impact. If trips on e-bikes are replacing trips on motorised vehicles, then there can be savings in CO2 emissions and energy. Trips by e-bikes might also be quicker and more direct than trips on public transport, so that would be a positive impact for the employees using the e-bikes (facilitating their daily job tasks, being more productive, reducing time spent travelling in the course of work).

Indirect impacts:

Immediate positive effects have been seen on the health of users thanks to the physical exercise practised by riding the e-bike and changing the level of assistance as their fitness levels increase.

Users of the e-bikes could become champions for this transport mode and become role models for other people to try e-bikes, at work, but also more broadly among personal and professional connections. Health benefits are also a possible outcome, therefore a potential indirect impact would be an increased awareness of the benefits of e-bikes among other businesses and community orgs. Organisations using these bikes can become promoters of the e-bikes.

Market analysis: enablers and obstacles

legal framework:

There are no legal enablers for using e-bikes. Planning permission is an essential element in placing cycling infrastructure in Bristol.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Incentives

There are financial enablers such as a significant reduction in costs for businesses in comparison with pool cars and paying mileage for staff to use their own cars.

Human factor (success factors, opposed sentiments, …)

- Knowledge of the area – consider whether the scheme is suitable for the target area by looking at the demographics. Also look at whether there are organisations operating in the area that would benefit from e-bikes for whatever reason (cutting carbon, health & wellbeing, facilitating regular short journeys, cost savings etc)
- Knowledge of the market – consider the existing and upcoming schemes in the area. It is important to be competitive.
- Ease of use – create a model where the client has to do as little as possible to be able to use the e-bike (e.g. provide regular service and support package, integration of bike onto booking system etc)
- Customer Service – Build relationships based on trust and respect – offer clients a trial period with the bikes and make sure that you are prepared to signpost potential clients to other options if the e-bikes are not for them. Make sure that you provide a support package that is prompt, responsive and effective with the aim of keeping people cycling (e.g. provide a courtesy bike if you need to take a bike away for repairs).
- Quality bikes: e-bikes need to be robust, easy to manage and suitable for a wide range of users.
- Deploy a dashboard that provides an intuitive web front end through which researchers are able to explore and understand the data.

Competitors

It must be mentioned that the introduction of a dock less bike hire scheme in Bristol soon after the start of the project had the impact of changing the market completely

First findings and scale up analysis

Lessons learnt

Schemes should be targeted at organisations that are historically providing combustion engine vehicles to transport staff around for short journeys in the community.

Secondly, it is inevitable that there will be corporate e-bike users that are already riding their own bikes and there is value in developing e-bike 'champions' within organisations to encourage others to take up riding the e-bikes.

Optimal scale for next implementations

The e-bike monitoring system has been designed with scalability and replicability of deployment in mind adopting the modular design, use of COTS components, 3D printing and PCB layout files to ensure fast and efficient manufacture at significantly reduced cost.

To create a sustainable scheme for the longer term there must be an emphasis on the benefits of the scheme to each organisation, with a strong focus on the cost savings created. The scheme has the potential for significant financial impact related to fleet solutions and human resources.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Expected impacts in the next future

It is expected that the introduction of e-bikes into organisations will promote social inclusion and improve access to sustainable and active transport. The scheme will also help support modal integration by acting as a catalyst to making more trips by cycling, walking and/or public transport. UWE will monitor the user experience and travel behaviour impact of the e-bikes. This will be achieved through a combination of online surveys of users and qualitative interviews with a smaller sample of volunteers who complete the online surveys. Both methods will also make use of the data collected by the trackers fitted on the e-bikes.

Additionally, if rolled out across the city on a much larger scale, it may have a positive impact of less traffic on the roads and lower levels of congestion, leading to lower levels of stress and a more enjoyable city environment with an improved quality of life.

Solution 4: ParkUs

Main partners involved: Toshiba Research Europe Ltd supported by University of the West of England (UWE) and Bristol City Council.

Short description of the action

By definition MaaS aims to encompass a wide range of modes. The key is to provide users with excellent information such that they can use the most appropriate mode of travel for their journey. For a range of reasons private car use is likely to remain the chosen mode for some journeys for the foreseeable future.

Therefore, personal vehicles are here to stay and where it may be impossible to totally eliminate their impact on the environment, the aim is to reduce this impact. The real time parking availability information system has been motivated by this objective.

Recent studies show that a key contributor to congestion and increased CO_2 emissions within cities are drivers searching (or cruising) to find a vacant on-street parking space. It has been shown that approximately (depending on the city) 20-30% of vehicles in congested urban areas were cruising to find a parking space with a parking search time varying in the order of several minutes.

In the city of Bristol alone, Toshiba has shown, using their collected trip and publicly available census data that over 790 metric tons of CO_2 is generated every year due to cruising at a total cost of £368,000 (US$467,000) in terms of fuel wasted.

This waste could be avoided if useful parking availability information was made available to drivers. Whilst we may not be able to eliminate cars from the roads, even a small reduction in the park search time can lead to significant reduction in the time, fuel, and money spent and reduce the impact on the environment by reducing emissions. Whilst the benefit may appear to be small for an individual user, the cumulative effect can be quite significant. Therefore, one of the aims of this activity is to reduce parking search times using data gathered from other road users.

Since 1950 the proportion of people living in cities has been increasing. A 2014 UN urbanisation report estimates that 54% of the world's population live in urban areas. This proportion is expected

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

to rise to 66% by 2050. As cities continue to grow in population and overall size, further demand is placed on transportation infrastructure such as road networks. Vehicular congestion is a major problem in most cities in the world and is likely to get worse in light of the aforementioned trend.
Providing users with real-time parking availability is a widely researched problem. However, most of this previous work presents solutions from one of two main categories. First, those that rely solely on parking availability information manually inputted by the user, such as Alphabet's now-discontinued OpenSpot project, and ParkJam. Secondly, there are those that use physical infrastructure, such as sensors in parking spots and CCTV footage of parking spots. These require huge upfront investments for development, installation and ongoing costs for maintenance. For example, the SFPark project in San Francisco cost $23M to equip 6,000 (less than 25% of) on-street parking spaces with sensors connected to the Internet. As a consequence, recent research has focused on finding ways to monitor in real-time parking occupancy without incurring huge physical infrastructure set up and maintenance costs.
Toshiba's previous effort, ParkUs 1.0, attempted to achieve this by automatically detecting parking and un-parking events using a driver's smartphone accelerometer and magnetometer sensor data (no user input or separate infrastructure installation was required). Although more accurate and energy efficient than its competitors such as PhonePark, Park Here and Park Sense respectively, ParkUs 1.0 was not able to detect driver cruising behaviour.
Detecting cruising combined with parking activity has a major advantage when it comes to providing real-time parking availability information. By detecting solely parking and un-parking activities the system only collects one data-point, such as where and when the driver parked and un-parked, thus yielding little information about the parking availability on nearby streets. On the other hand, detecting and monitoring cruising behaviour allows to infer the availability of parking spaces on multiple streets. As it is assumed that a driver would park as soon as they find a vacant spot near to their desired destination. Therefore, the system can infer with reasonable certainty that there were no vacant parking spaces along those roads or parking bays that the driver searched shortly before they parked. Consequently, it can now advise other users looking to park in the same area not to waste time by (re-)searching those streets or car park, as they are most likely full. Instead ParkUs can potentially suggest a better search strategy or use of public transport instead.
An important aspect of ascertaining parking availability is to reliably identify and eliminate areas where parking is not available. It is well-accepted that detecting a cruising event is a proxy for lack of parking. The ability to detect cruising and use this information to update parking availability information has been the focus of the work so far and has resulted in the development of the ParkUs 2.0 app.

Value proposition

Use of the ParkUs app can provide a number of benefits including reduction in congestion and therefore in vehicle emissions, time and money spent on fuel. There are high volumes of daily work commutes in the city of Bristol (28,500 daily trips). We aim to reduce the amount of time spent during these trips that will not only result in less CO2 emissions but also time and money savings.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Technology

The solution in use

The solution plans to use a smartphone in conjunction with a backend server system to detect parking activities. By logging sensor and location data and using this to train a machine learning model, it is possible to detect cruising behaviour which can be used as a proxy for non-availability of road segments on which the vehicle cruises. Combining this information along with the location where the user parks, can be used to update the heatmap of parking availability information at the central backend server. Updates from all the user data can be easily aggregated and displayed to other users also searching for parking in their area of interest. In the instance where no user reports are available in a particular area, parking availability is marked as "unknown" and displayed with "grey legend" in the heatmap. Thus, the more users that contribute information to the system, the more accurate is the information maintained by the backend system and available to the users.

- *ParkUs System Design*

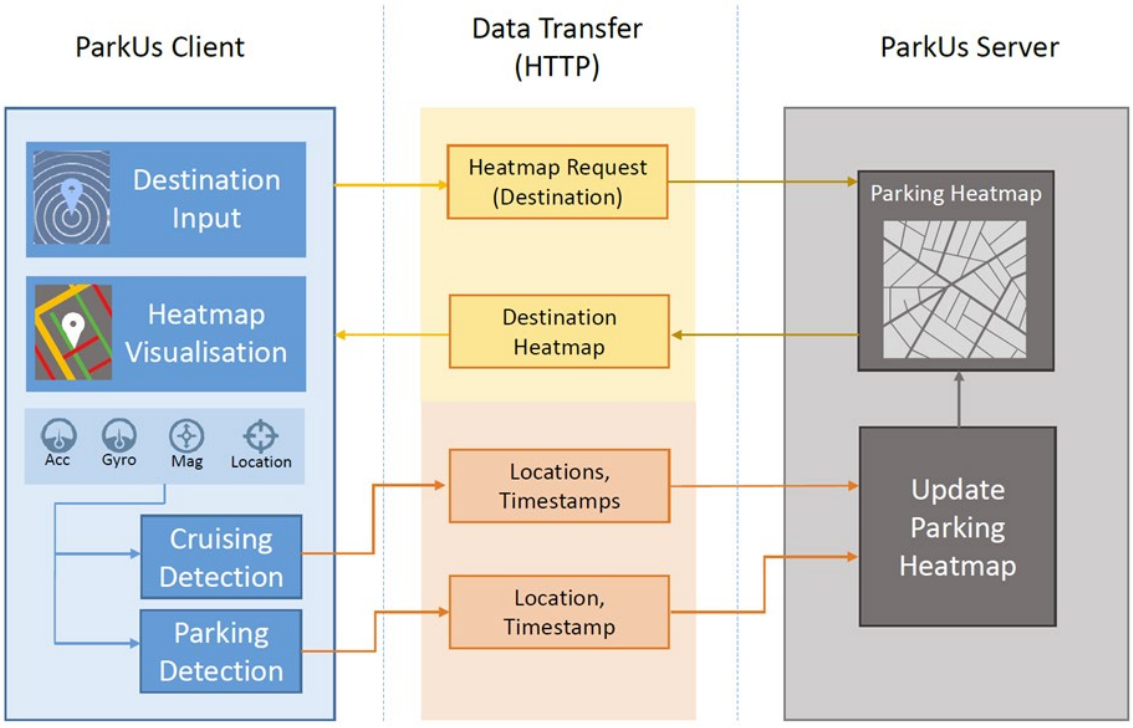


Figure 8.5 – ParkUs System Design

ParkUs is a crowd-sensing based solution which has been realised as an Android smartphone app augmented with an intelligent backend system (see Figure 8.5). The app collects location and sensor data from the driver's smartphone, uses a machine learning model to pick up patterns relating to 'vehicle cruising behaviour' and uses this in addition to input solicited from the vehicle driver (app user) once they have parked to update probabilistic parking availability information on the backend server.

The proposed cruise detection system relies on the principle of detecting a significant local minimum in the GPS trace with respect to distance from the destination. In addition to GPS data,

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

other sensing data from the driver's smartphone such as accelerometer, gyroscope and magnetometer were also collected and it was found that features extracted from such sensor data can help in training models and effectively detecting when the vehicle does and does not cruise. Such information augmented with input from other users in the area (drivers flagging a parking event) can be fused together to build a picture of parking availability in that area which can be made available to the end user.

When a user enters their desired destination address or postcode before beginning the journey, the app displays a heatmap of parking availability in the destination area within a radius specified by the user. The backend server keeps updating the road-by-road parking information as new data is received from other users in the destination area and sends an updated heatmap periodically to the smartphone app thereby resulting in a refresh of parking availability information.

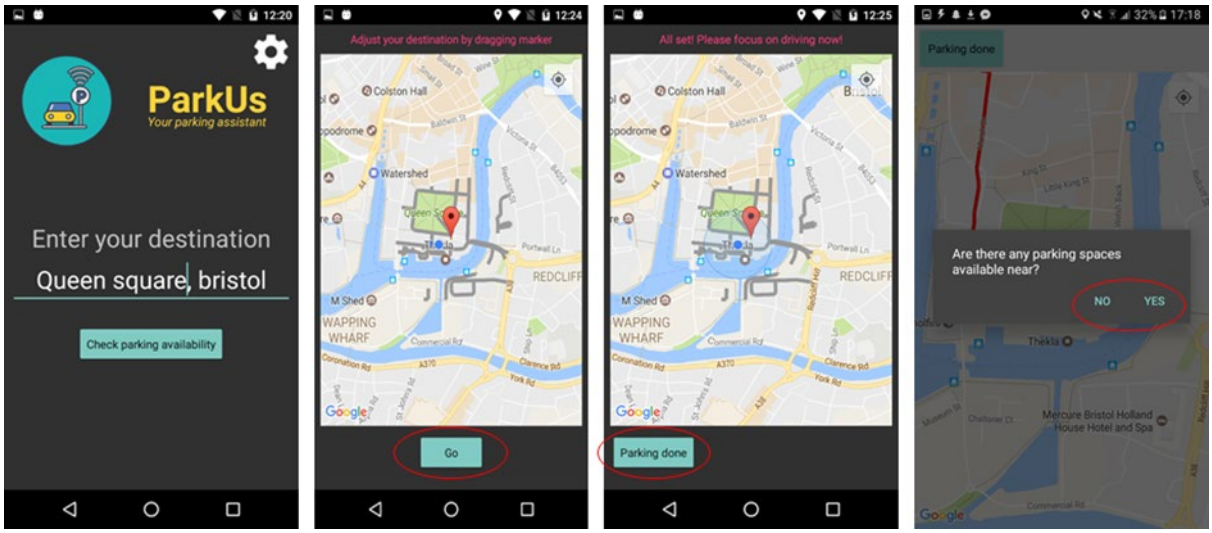


Figure 8.6 – Screenshots of the ParkUs app showing the different steps involved

Figure 8.6 shows screenshots of the app depicting the steps involved in using the app. The user enters the destination street name / postcode and clicks on 'check parking availability'. This displays the current heatmap within a 200 meters radius of the destination. As seen from the figure, the streets coloured 'Grey' indicates parking availability unknown. This could be because no one has yet reported data from this destination area or that the information available for the destination area is stale. As more and more users use the app, the accuracy of the heatmap will improve.

The user then clicks 'Go' and starts driving to their destination area. On arrival and after parking, the user clicks on 'parking done' to indicate they have parked. The app then asks them to indicate whether parking is available in the vicinity (based on a quick visual glance around) and followed by a simple 'yes/no' click. The backend then averages reports received from multiple users in a destination area to update the heatmap (e.g. Green indicating high likelihood of availability, orange indicating medium likelihood of availability, red indicating less likelihood of availability and so on) which would be useful for the next users querying for parking information in this area.

An important point to be noted is that the app has been designed to comply with typical motor regulations in most countries which prohibit the driver from using a phone whilst driving. The user

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

only needs to interact with the app before setting off on a journey and after parking at the destination which makes it practical from a deployment perspective.

Whilst making vehicle parking information available on a smartphone is not new, the novel aspect of the ParkUs system is automatic cruise detection using sensor and location data and a parking availability inference system which requires minimal user interaction. This is the very first approach using machine learning to detect cruising behaviour. The benefit of detecting cruising in the destination area is that this could be considered a proxy for lack of availability of parking which can be useful to update the probabilistic parking availability on the roads where the driver is found to be cruising.

Figure 8.7 shows the flow of data from the sensors on the smartphone to the set of labelled feature vectors to train a binary classifier. It also shows the flow of data once the classifier has been deployed, and the distance-based labelling is no longer needed. The advantage of the proposed method is that data can be automatically labelled. To start with sensing data is by default labelled as 'not cruising'. As soon as the significant minimum point is crossed, data is automatically labelled as 'cruising'. Such automatic annotation (or labelling) of data has tremendous advantages since it reduces the time required to annotate the data (compared to manual annotation) and the time spent training the model. Furthermore, the driver is not required to interact with the phone during driving, thus ensuring compliance with the law.

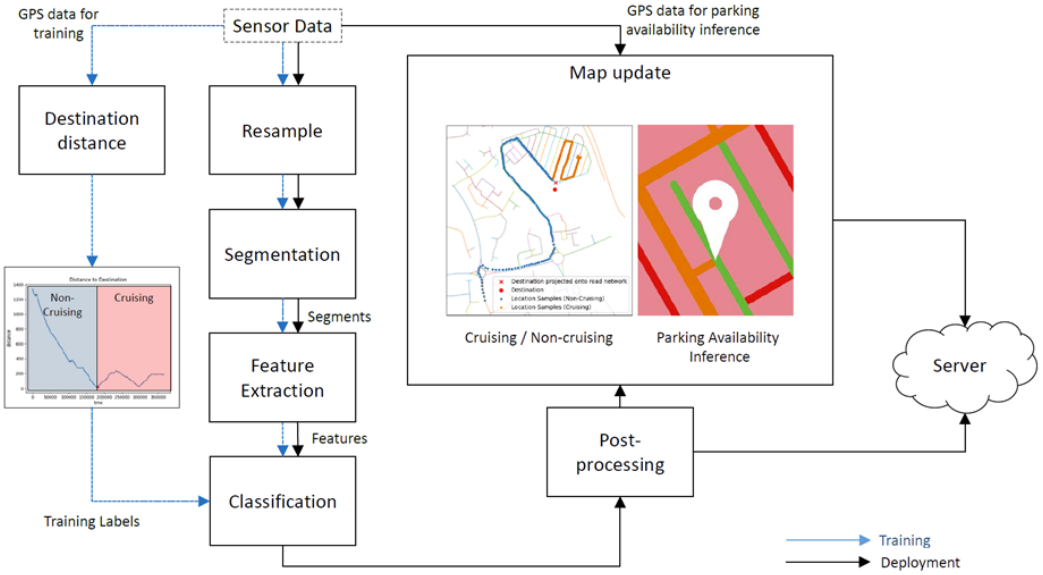


Figure 8.7 – Data flow pipeline for training and deployment of the ParkUs system

- ParkUs Trials

Sensor data from a total of 41 journeys was collected from 5 Toshiba volunteers over a period of several weeks between March and June 2017. Accelerometer and gyroscope data were sampled at a rate of 25Hz, while magnetometer data was sampled at a rate of 5Hz. Location data from Google's Fused Location Provider API was sampled at 1 Hz. For each journey, volunteers were asked to record their desired destination before setting off in their vehicle. The smartphone sensor data (such as accelerometer, gyroscope and magnetometer) were then collected along with GPS data for the entire journey until the user parked at their destination and pressed a 'parking done' button (as described

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

earlier) in the application. Sensor and location data were then uploaded to a server where it was further processed. Furthermore, volunteers were not restricted in placement or orientation of their smartphones during the data collection phase. With the aim of maximising the generality of the cruising classifier, the data was collected at several locations across the city of Bristol, UK.
Manually identifying and labelling the starting time of cruising for each journey would be a time-consuming and error-prone task. To mitigate this problem, the method of determining this timestamp was automated taking into account the observation that in a typical journey in which cruising occurs, the distance to the destination will decrease until it hits a local minimum. At which point the distance increases again as the driver starts moving further away from their destination in the search for parking. This minimum might be caused by the driver passing by their destination and observing that no parking is available, or it might be caused by a circular route or S-shaped curve as might be observed in a car park. Overlapping time windows were used to extract features from real-time sensor data.
Three classifiers were trained using the data collected from the trial; decision trees, support vector machines and k-nearest neighbour. The output of the classifier was then post-processed using a finite state machine in order to reduce the effect of the classifier producing short 'gaps' of non-cruising during true cruising, or cruising during non-cruising. In order to alleviate the potential bias introduced by cross validation schemes such as in a standard k-fold cross validation scheme, a leave-one-user-out cross validation technique was applied during all steps of training and evaluation of the classifiers. It was found that SVMs outperformed the other techniques achieving an accuracy as high as 81% in being able to predict cruising events.
The evaluation of ParkUs is ongoing with another trial recently concluded at UWE in Bristol, one of the partners in the REPLICATE project.

Innovation level

While detecting parking using a smartphone is not new, the novel aspect in our case is automatic cruise detection using sensor and location data and a parking availability inference system which requires minimal user interaction. These are challenging problems indeed. The aim is to detect when users are searching for a parking space as this will provide the system with more information with regards to parking occupancy levels; e.g. for every street (near to the desired destination) a driver drives down and which he does not park on, is considered to be full. Thus enabling ParkUs to infer much more information from just simply a single detection. This final aspect is very novel and to partners' knowledge has not been tackled in the literature as of yet. This could additionally be augmented with user input at the end of the journey soliciting information on spaces available in the vicinity through a quick glance, thereby providing valuable ground truth which could improve the accuracy of information provided to the users.

Main impacts of the measure (economical, environmental, social)

Direct impacts

As highlighted earlier, the aim is to improve the parking availability information for the app user which will likely result in reduced congestion (due to reduction in the amount of time required to

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

find parking), associated CO_2 emissions and the time and money saved in the process. Toshiba conducted a preliminary trial in Bristol within which cruising data was collected. Using publicly available UK census data on daily work commutes they were able to estimate the total number of daily trips (around 28,500) made by vehicles into the city centre of Bristol. Considering the distance travelled during a typical cruising journey and the time spent searching for parking (as reported in our dataset), it could be estimated that the city centre of Bristol produces over 790 metric tons of CO_2 that can directly be attributed to cruising. The solution aims to reduce a major portion of such emissions with the help of an appropriate deployment of the ParkUs app in the pilot area. Economically, it is estimated that around £368,000 worth of fuel is consumed when cruising (considering the fuel prices, average fuel efficiency of a car, time spent cruising as reported in our trial).

Whilst tracking reduced congestion is more difficult to quantify, it may be possible to get information from the user on their perceived amount of time saved trying to find parking on average through qualitative surveys/questionnaires. Based on such a rough estimate, one can then calculate estimated reduction in CO_2 emissions and the costs associated with fuel saved. One of the other aims is also to nudge the drivers not to use their vehicles as much as possible. The latter we reckon could be achieved if users see that there is no parking near to their destination and as a result decide to walk or take a bus instead. Whilst hard to quantify this such information could be gleaned from qualitative surveys/questionnaires.

Indirect impacts

Reducing congestion has many indirect impacts. Firstly, it reduces air pollution and secondly, it potentially lowers road fatalities (because less vehicles are on the road). There may also be the added benefit of inducing the user (based on lack of availability of parking) to use other modes of transport such as shared/public transport where a vehicle could have been used otherwise.

Market analysis: enablers and obstacles

Legal framework & incentives

Toshiba application relies on many users in order to collect adequate amounts of parking data to provide useful parking availability information to other road users searching in the area, therefore in the interests of gaining a critical mass, it is vital that the app be provided for free. The app could also be provided as a feeder or applet in the larger TravelWest application. From the perspective of legal implications of using the app, the user is expected to fully comply with the law and therefore will require to interact with the app only "before setting-off" and "after parking the vehicle", and not while driving.

The app has been designed with the aim of minimising the volume of data reported by the end user device, however there is a need to report data on the go. To accomplish this, cellular coverage is vital which is not an issue in the trial area.

Human factor (success factors, opposed sentiments,…)

As highlighted earlier, the success of the app depends on the level of uptake. Based on initial trials, Toshiba was able to establish a significant interest in the app for example, in a post-trial survey of the UWE trial with 15 participants and over 85 journeys in 6 weeks, it has been found that over 85% of users are willing to use a parking app for the greater good. Over 60% felt that using a parking

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

app could reduce their car's environmental impact. In this survey, it was also observed that over 78% of users felt that the government thinks they ought to be more conscious about their car use and its environmental impact. This percentage is significantly low when it is about what the family, friends and neighbours think about their car use (7, 0, and 10% respectively) suggesting a lack of awareness in public about the environmental impact of car usage in general.

The key obstacles are several fold: getting enough users to sign up to the service and providing accurate information on parking availability at the same time would be a challenge. Getting people to use the application will be hard, as there are few benefits to the early adopters as also observed in our initial trials. It is not clear whether providing some incentives to early adopters would suffice. Remembering to use the app is another issue which partners have found to be an important one based on the early experience. Even if a user were to sign-up for using the app, sustaining an engagement with the user, in particular, ensuring that they continue using it on an ongoing basis would be a challenge. Whilst validation of the app is vital prior to roll out, such validation has to be conducted through controlled tests. On the other hand, critical mass is essential to validate the app in an uncontrolled setup which can be quite challenging. Furthermore, given the app relies on crowdsensing which does not have knowledge of fine-grained parking information but instead coarse grained probabilistic information, maintaining accuracy of the information will be a challenge.

Competitors

Whilst there are a few start-ups who seem to be trying to achieve similar goals but mainly targeting infrastructure driven solutions; their methods and data are also not publicly available. As such there are no direct competitors since our solution is looking at all types of on-street and off-street parking whereas other players mentioned above are mainly targeting car parks and pay and display zones.

First scale up analysis

Realising a crowd-sensing based parking availability information system is complex. Without the app reaching a critical mass of adoption it will not be possible to provide accurate parking availability information. At the same time, without providing accurate parking availability information it is difficult to reach critical mass. It is essential for many users to be using the application on an ongoing basis such that up to date parking information can be recorded and displayed to the users. Whilst public outreach and engagement is vital to accomplishing this, enlisting a large number of users to start with would be quite challenging as our initial experience suggests. Getting early adopters to regularly use the application is a challenge, as there may be little benefit for them initially. One way to work around this is to conduct trials in smaller areas of the city by employing a set of participants that live or work within these target areas. Once localised groups benefit from other users regularly using the app, the credibility of the application will be established and in turn will likely lead to more drivers using it.

Lessons learnt

ParkUs has been tested in various trials and therefore has seen several stages of development. As detailed above, the first version of the ParkUs app targeted the detection of parking activity alone.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Although this approach produced a highly efficient and accurate method for parking detection, it was only limited to the parking bay in which parking was performed. In order to overcome this, Toshiba developed a method for cruising detection and inferring parking availability based on this information. The app was re-designed for ease of use and machine learning algorithms were developed such that they can readily be used on the mobile platform (previously not possible with the first version of the app).

Optimal scale for next implementations

The app has been designed with scalability in mind. As it stands, the backend has been fairly over-provisioned and will easily cater to small scale trials involving hundreds of users. Scaling this to thousands/tens of thousands of users will require appropriate dimensioning of the backend system. Since the app requires reporting data in real time, users would need access to cellular coverage (3G and higher connectivity should suffice).

Further developments needed

As mentioned earlier, validating the premise of a crowd-sensing based parking availability app will require a lot of testing and refinements. Whilst a decision was made to develop the app for the Android platform given its ubiquity and ready availability of hardware to facilitate rapid prototyping, a similar app could be developed for other platforms such as Apple as required. Further, efforts will be required to maintain the app and ensure compatibility with evolving versions of the operating system.

Expected impacts

Given that the app caters to older versions going back to Android 4.4, a large spectrum of devices is already supported and therefore do not see any significant impact of this on a roll out. However, if major API changes happen in newer versions of the app this could cause compatibility issues with devices running the older version of Android.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Solution 5: Multi modal journey planner

Main partners involved: Route Monkey, Bristol City Council

General description

Route Monkey's client for this product has been (Travelwest) TW, which is part of Bristol City Council and owner of the current Travelwest journey planner (TWJP).
The product supports the achievement of TW's policy goals to:

- Deliver an *improved journey planning service* to both citizens and tourists, with a focus on multimodal journeys and personalised service
- Reduce *road congestion* in Bristol City Centre
- Encourage *behavioural change* towards use of alternatives to car transport, particularly for regular journeys and major events.

Travel planning typically begins with a journey planner. For example, a trip planner can show that the user can get from one destination to another by using a train/bus combination. The user can then choose their preferred trip based on cost, time, and convenience. At that point, any necessary bookings would be performed as a unit. It is expected that this service should allow for roaming, so that the same end-user app should work in different cities, without the user needing to become familiar with a new app or to sign up to new services.
It is with the Mobility as a Service (MaaS) concept in mind that the Travelwest Journey Planner has been developed. By integrating new data via new Application Programming Interfaces (APIs), the Travelwest Journey Planner provides new optimised personal mobility opportunities. It goes beyond what is currently available through commercial providers and opens up opportunities in terms of new ways of understanding urban travel. Travelwest is the one-stop website for travel information in the West of England, however you like to travel. Figure 8.8 shows the existing Travelwest home page.

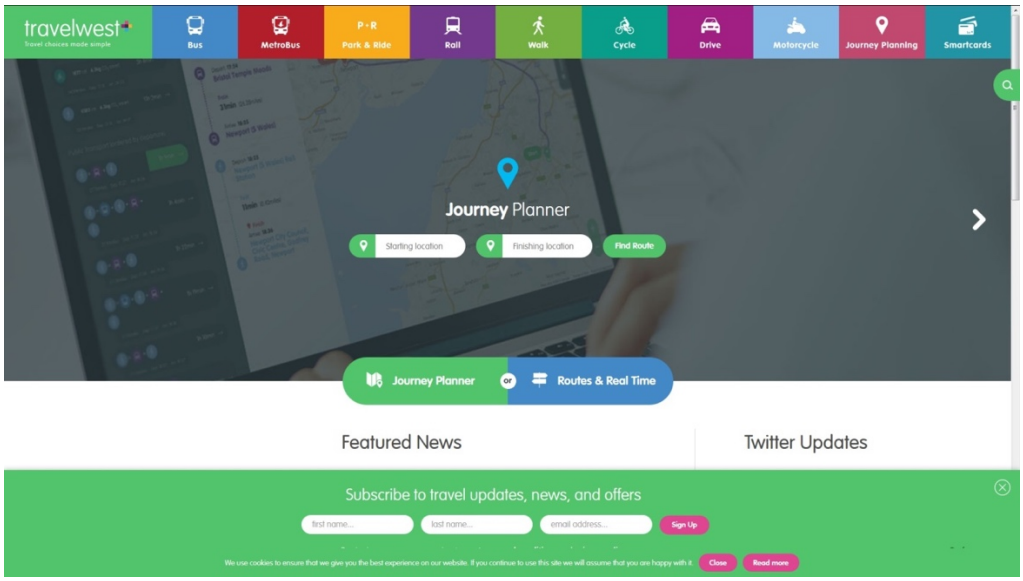


Figure 8.8 – Existing Travelwest website homepage

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Its aim is to provide users with all the information they need in the simplest way – to help make their life easier, healthier and save them money. By encouraging the public to grab their bike or trainers, or to catch the bus, it keeps users informed about initiatives implemented across the West of England to promote sustainable and active travel options relating to public transport, walking, cycling, car sharing and electric vehicles, while also providing useful resources for schools, businesses and developers.

Travelwest was funded via the Local Sustainable Transport Fund provided by the UK Department for Transport until 31st March 2016. Since 1st April 2016 it has been funded by the four Local Authorities comprising the West of England: Bristol, South Gloucestershire, Bath & North East Somerset and North Somerset.

The Travelwest Journey Planning web app allows users to find their journey options, real-time information for buses and trains, their nearest bus stop or train station, bus service routes, and much more. Prior to REPLICATE, however, it had limited multi-modal functionality and only catered for a subset of journeys as it did not offer journeys with certain combinations of travel modes.

Partners involved in the TWJP are Bristol City Council (BCC) and Route Monkey.

Route Monkey has specifically introduced the following two aspects to the TWJP:

- Car + Park & Ride (P&R)
    - Incorporating considerations of cost and convenience for different parking options relevant to encourage shift away from using the car for the whole journey
    - P&R waypoints include the three P&R sites in Bristol – Portway (NW), Long Ashton (SW) and Brislington (SE).
    - Bristol Parkway train station is also included as a P&R waypoint – this is in NE Bristol and has ample parking and frequent trains to Bristol Temple Meads. Hence it is suitable for commuting, reducing traffic through the project area.
- Cycling + Train

Value proposition

These new components of the TWJP raise awareness of alternative means of multi-modal travel within the Bristol area, for both business and leisure journeys. In addition, they support delivery of Bristol's specific objectives (sustainable mobility, improvements to health and wellbeing, access to training and employment, Citizen engagement, behaviour change and CO_2 emission reduction) and TW's policy goals of improved journey planning, reduced road congestion and behavioural change. It reduces congestion and CO_2 emissions in the district by presenting all sustainable travel alternatives on the Travelwest website, by different modes of transport, to travellers passing through the district and residents. Additionally It improves the mobility of residents of the district by presenting all sustainable travel options available for their leisure and commuting journeys. And it is with the principles of MaaS in mind, the Bristol REPLICATE partners have been upgrading the Travelwest journey planner.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Technology

The solution in use

The solutions will be integrated in the current Travelwest Journey Planner, available at travelwest.info/jp. This Journey Planner is built in AngularJS, the algorithm created by the partner, Route Monkey, will be available in JSON.

Route Monkey technical feasibility and approach

A series of face-to-face scoping meetings and calls were undertaken between Bristol City Council and Route Monkey between June and August 2016. During this period the strategic priorities for Travelwest were discussed and evaluated by Route Monkey and subsequently actual deliverables were agreed as above.

Solution development strategy

The project plan was based on a solution development strategy which starts at the simplest end of the solution complexity spectrum and progresses in stages towards the most complex end by adding functionality at each stage.

The additional functionality at a given stage will allow the resulting solution to accommodate changes in:

- Algorithms used (A)
- Waypoint types considered (W).

It may also involve revisions to input and output data specifications, in line with the above updates. The algorithms will be advanced in a development environment for subsequent use within a production environment, as follows.

- Development environment

The first step is to design and build a development environment providing the core systems that are required to support the development of additional functionality in line with the above strategy. This stage will include set up development, integrating with external APIs and set up of the development database. Once the development environment is in place, the work will incorporate algorithm development with the learning aspect being added at the algorithm refinement stage.

- Production environment

The work will then progress to building production systems to incorporate the solution created under the development environment and integrating this with Travelwest systems.

This will involve setting up the cloud infrastructure, configuration, integration with Travelwest, testing and ongoing technical support, hosting and licensing. Development of a new Travelwest Journey Planner front end

- Development of the Framework - User Experience (UX) and Design

The wire-framing and prototyping phase is complete. This has been approved and signed off.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

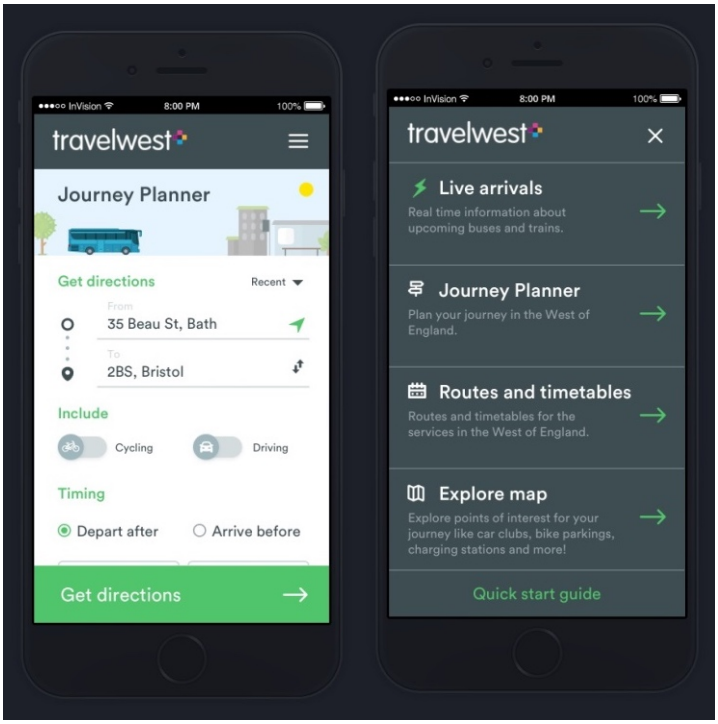


Figure 8.9 – Screenshots of the designs:
mobile version (refreshed home page and new "Include Cycling" and "Include Driving" options)

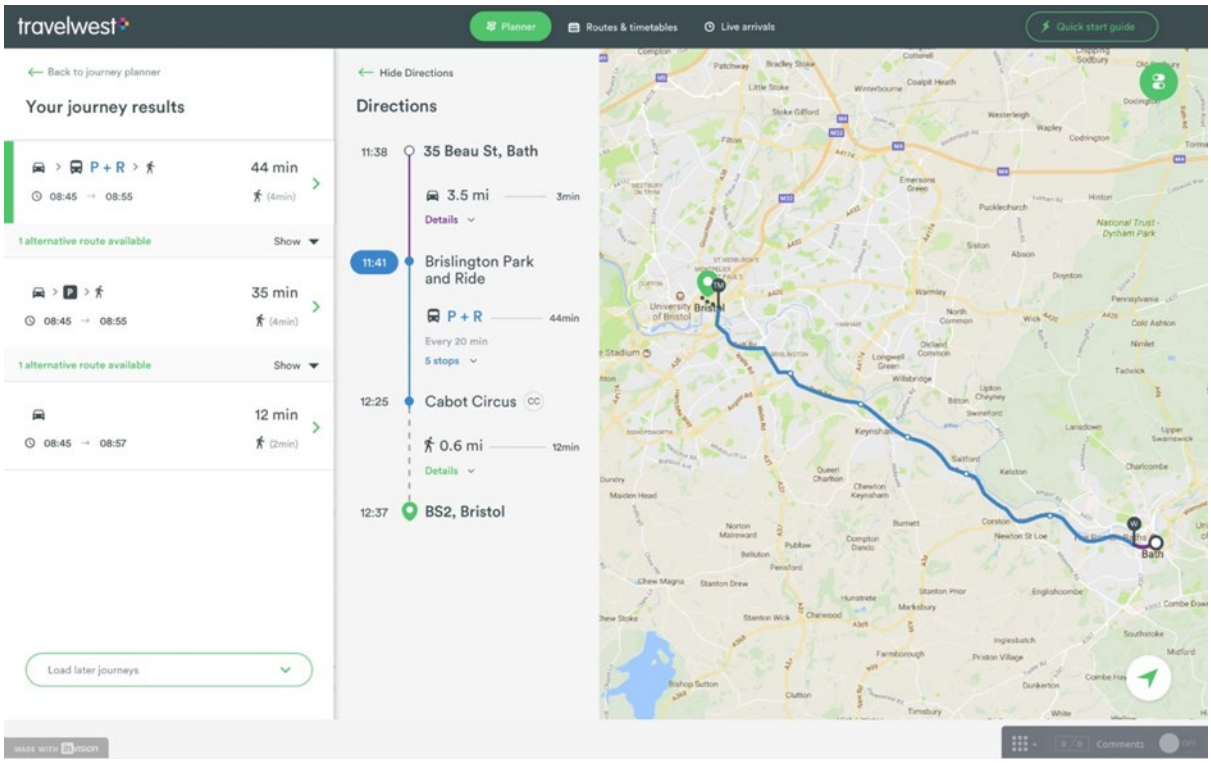


Figure 8.10 – Screenshots of the designs:
desktop version – showing new car and Park & Ride option

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

- User Testing

User testing was carried out throughout the project on both Mobile and Desktop layout. This was done through 'on-the-fly' research around Bristol. It involved asking a specific question to a person and observing how they used the tool to find the information. The findings directly affected the design, User Interface, User Experience and how best to optimise the user journey.
Once it was apparent there were no major 'sticking points' during key user journeys, more in depth research was carried out which involved an interactive prototype of the app. The experience provided a realistic experience on how the app would look and function once complete. Users were asked a series of questions and talked through their actions and what they would expect to see when completing a set action.
The results from user testing show that 100% of the testers would use these journey planning tools, and that multimodal journey options are popular with potential users.
A detailed User Testing Report was also produced. This outlines the significant evolution of the product following user testing and Integration of the APIs with the upgraded Travelwest Journey Planner

- API integrations

The Journey Planner is functioning as expected and the APIs are integrated:

- South West Public Transport Information (SWPTI) – Successfully integrated. When developing the interface, the data was checked to ensure it was in line with the designs.
- GIS – Successfully integrated. Waiting for Bristol City Council GIS to update the API feed so the data can be fetched.
- Google – Successfully integrated.
- Bristol Urban Things – Successfully integrated. Waiting for Bristol City Council GIS to update the API feed so the data can be fetched.
- Route Monkey – Successfully integrated. Confident in the functionality of the app, i.e. results are being plotted, including the new multimodal transport options and offering desired functionality outlined in designs. Route Monkey, Bristol City Council and the web developer (Green Chameleon) are reviewing the quality of results to confirm there aren't any discrepancies or irrelevant results returned.
- Map Layers – All layers have been successfully integrated. Waiting for Bristol City Council GIS to update the API feed so the data can be fetched.

Innovation level:

This will be the first Journey Planner developed for Bristol which will successfully combine in an intelligent way all of the following when calculating journey options: Car Parks, Cycling, Rail, Bus, Walking, Driving and Park and Ride locations.

Main impacts of the measure (economical, environmental, social)

Direct impacts

Route Monkey does not have access to data that could support a before and after impact assessment. The algorithm returns an answer to a journey query but does not record individual user journeys for analysis.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Indirect impacts

Overall, the indirect impacts include better travel information for access to work or training opportunities as well as socially, by encouraging behaviour change towards more sustainable travel, reducing congestion and increasing health and wellbeing.

The practicality and benefits of upgrading the journey planner to allow for these strategic priorities was assessed with the following upgrades considered possible within the REPLICATE project:

- P&R and Car multi-modal planner. This offers motorists an alternative to driving into the city centre and encourages use of multi-modal transport by suggesting that they park their car in one of the Park & Ride sites located on the outskirts of Bristol and continue their journey on one of the dedicated bus services.
- Cycle and Train multi-modal planner. This functionality allows users to identify cycle hire locations and plan a route around the city (and beyond) by incorporating train and bus services.

Market analysis: enablers and obstacles

Legal framework & incentives

Route Monkey is an entirely private sector entity that undertakes work for public sector organizations, according to public sector procurement rules, and private sector clients, according to typical business-to-business relationships. This describes the typical situation for information-technology mobility services in the UK.

Human factor (success factors, opposed sentiments,…)

Users will be able to see virtually all the options available for their travel needs by any mode of transport. This new upgrade will be a good base to continue to apply small upgrades to the Journey Planner in the future based on local travel needs.

Behaviour change will depend on the user's state of mind towards accepting the change.

Users will have to be made aware of the new functionalities of the journey planner through promotional material, but visiting and trying the journey planner depends on the users' desire to do so. Positive user interactions are likely to encourage continued use and wider engagement by word of mouth advocacy.

Competitors

Traveline Journey Planner

First scale up analysis

Lessons learnt

This deliverable has successfully brought together a wide range of disparate data from a variety of providers and delivered it in an attractive, easy-to-use, personalised format. It is hoped that users find this beneficial and start to use the services which will lead to the need for further development as new multi-modal options are presented

Optimal scale for next implementations

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

New API's are becoming available all the time; this additional data (e.g. services, timetables, road conditions etc.) can be added to the existing functionality to improve the quality of the service whilst at the same time allowing the planner to remain relevant to the city.

Further developments needed

Some initial development considerations were:

- Price comparison between modes of transport.
- Real time incidents to allow re-planning of journeys.
- Pick & Mix journey leg selection (i.e. swap walking by cycling manually)

App Development

The app was tested at in an un-styled format to ensure that integration between the new Route Monkey API and the journey planner functionality works well. Quirks were ironed out and decisions made on which "unreasonable" journey options not to offer the user. A beta testing version is about to be 'soft' launched for further usability testing.

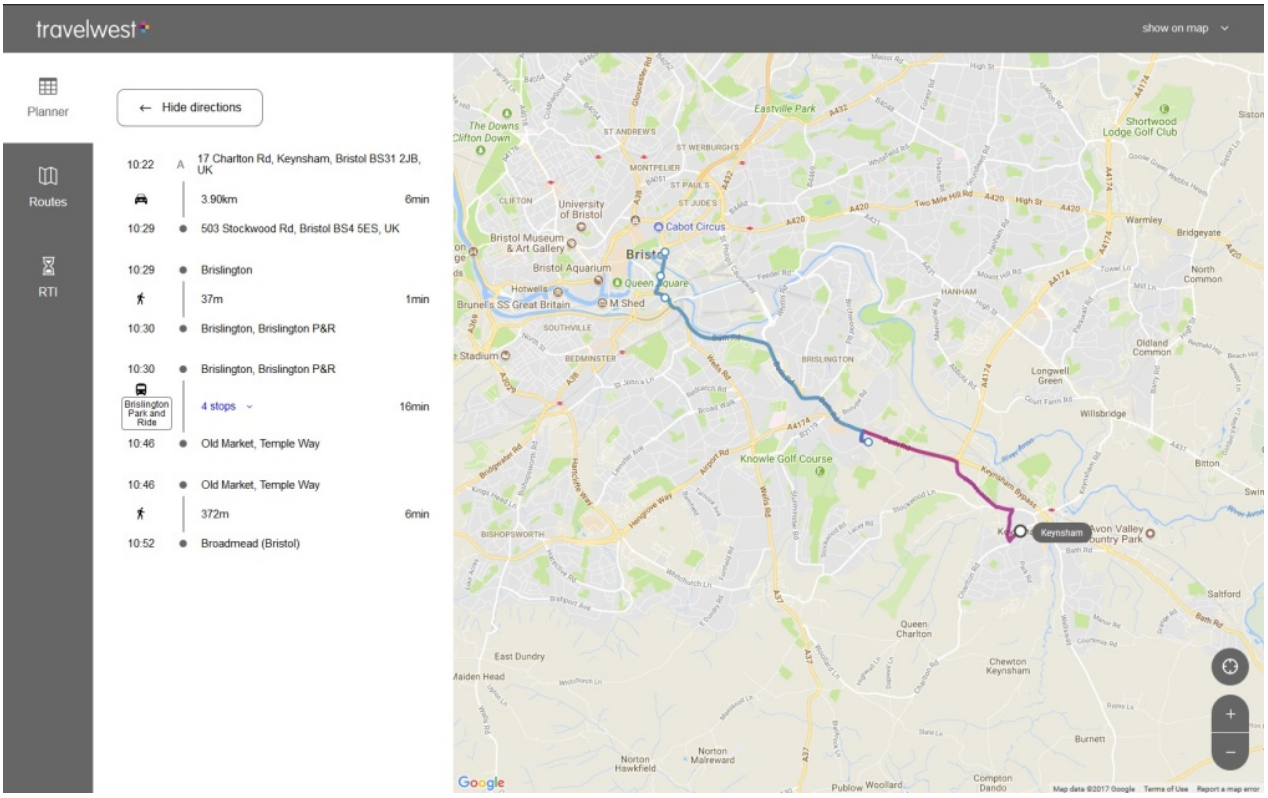


Figure 8.11 – Example showing real working example of the un-styled Journey Planner selecting a multimodal car + park & ride journey

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

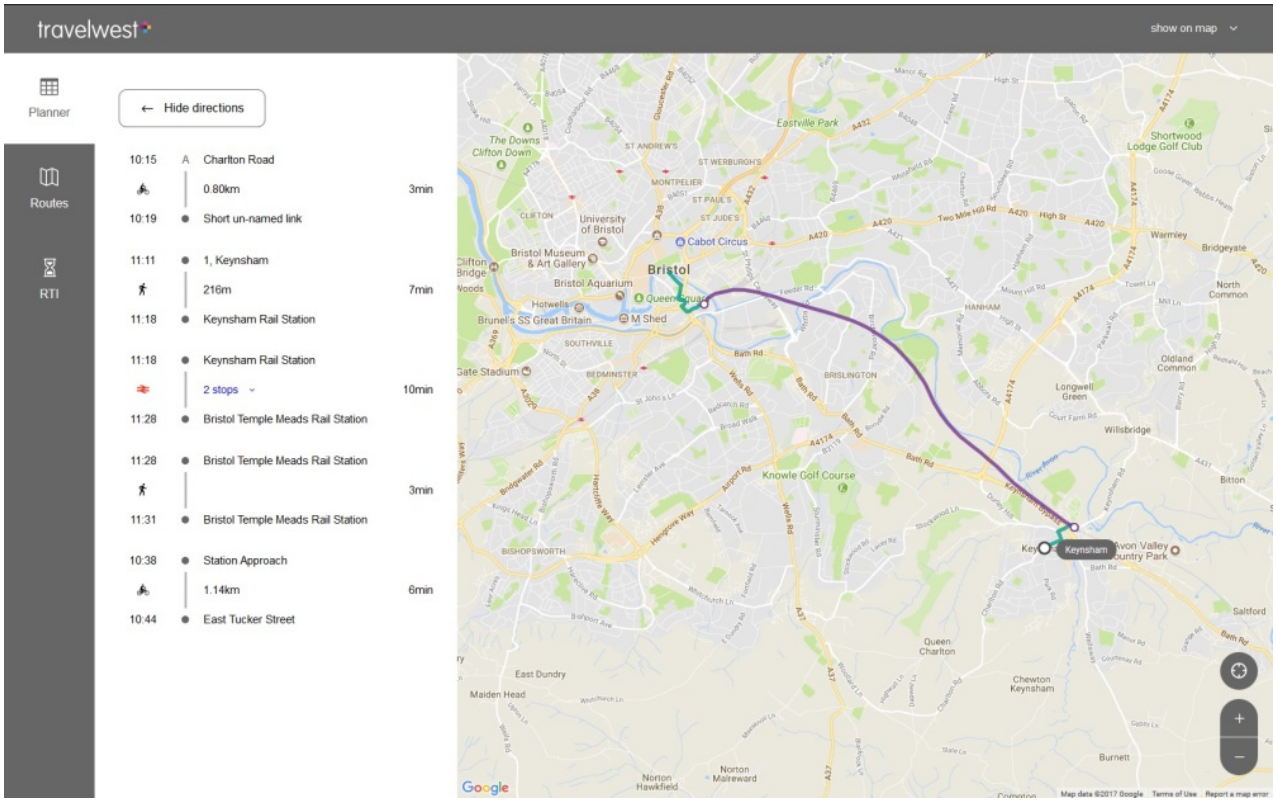


Figure 8.12 – Example showing real working example of the un-styled Journey Planner selecting a multimodal cycle -train-cycle journey

Figures 8.11 and 8.12 show examples of the working, un-styled, multi-modal Travelwest Journey Planner.

Expected impacts:

The Travelwest Journey Planner upgrade has highlighted a range of activities which will be essential to the wider roll out of optimised personal mobility solutions.

Data from a variety of sources has been identified from a range of static and dynamic sources; these have been categorised, cleaned and made available through a number of platforms including GIS applications, an open data platform, Bristol's operations centre and "The Bristol API".

These have been brought together and repurposed using Route Monkey's algorithms to provide more customised journey solutions. Route Monkey has demonstrated the ability to provide customised responses to queries from the Travelwest Journey Planner via a new API that has been developed for this project.

The journey algorithm identifies alternative ways to break the journey and swap modes of transport, it is mode of transport agnostic and as such new transport modes can be added in the future to provide scale-up opportunities.

Bristol City Council has commissioned an upgrade to its existing journey planner to allow for a wider range of multimodal journeys. This goes further than products that are generally available on the

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

market. Both the back end and the front end would have substantial potential to be repurposed for use in other cities.

Another area where REPLICATE has broken new ground is with the connection to live bike hire data. Through Route Monkey's connections to the live YoBikes API, the journey planner is able to include cycle hire options with cycles that have non-fixed parking places.

The principles developed through REPLICATE will also be adaptable as new live transport data streams become available.

The creation of a flexible journey planner will allow for additional modal functionality to be added such as the green mobility options demonstrated in this project (On demand EV minibus and Electric Vehicle Car Club).

Some tailoring of the algorithm would be required for each city (identifying travel hubs and available modes of transport).

Whilst the current Journey Planner does not yet include payment (beyond signposting to payment options) in future it is expected that these will be integrated in to these sorts of platforms to provide truly integrated MaaS experience.

It is expected that providing users with better information will encourage people to use new travel modes and ultimately help reduce carbon emissions and congestion.

Solution 6: Smart Mobility platform

Main players: Ikusi, Fomento San Sebastian, ADS (San Sebastian Municipality),

Short description of the action:

A Smart Mobility platform has been developed in the project framework in order to optimize the urban mobility services. Applying Business Intelligence and Big Data technologies, the information collected from the sensors and operating systems of the city will be exploited. In this way, managers, service operators, municipal planners and citizens can obtain information in a simple and orderly way, which allows them to better understand the reality of the city.

The solution has a comprehensive web tool that allows users to exploit the ability to analyse and interact with different content through a centralized, secure and multi-user global vision. This interface shows information adapted to the needs of the different municipal departments (public transport, parking, traffic, etc.). The information can be displayed in different formats, such as dashboards or key performance indicators. All this information can be filtered to access only the specific data that interests the user. It also includes a tool to generate reports and a module to manage the events (incidents that occur in the city).

Regarding data analytics, the platform includes predictive capabilities. For this, several multiclass classification models can be implemented and trained with the data coming from the city. In this context, a prediction model has been developed to predict the level of bicycle occupancy of each station in the bicycle sharing system of San Sebastian.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Value proposition

The value proposition of the platform focuses on offering to managers and technicians of the Mobility Department answers providing useful information for the performance of their services (What has happened? Where is the problem? What actions are required?).
Thanks to all the information stored and processed by the platform, operators can make decisions based on real and truthful data, increasing therefore confidence and consensus in decision-making. In short, establish a comprehensive and effective management of urban services for optimal use of available resources.

Technology

The Mobility Platform centralizes, processes and exploits data in a multimodal way with advanced Business Intelligence tools. The solution is based on a robust, open, horizontal and highly scalable management approach. The information and communication architecture allows the development and deployment of advanced, efficient and sustainable services and applications for mobility service management. For this, the platform is able to monitor and analyse a large volume of data from multiple sources and operational systems from the different departmental services, which are related to the following areas:

- Cycling mobility:
  - System of gauges for counting of bicycles.
  - Public bicycle rental system.
- Parking:
  - Underground parking management systems: mainly occupancy data. Complexity to extract the detail of the individual data of time entries / departures / nationalities (for administrative, not technical reasons).
  - Surface parking management systems.
- Circulation and Traffic:
  - Gauges for vehicle counting (intensities)
- Public transport:
  - Operating system for urban public transport.
  - Operating system for ticketing data.
- Electric Vehicular charging points:
  - Stations that supply electric energy for the recharging of electric vehicles
- External data sources: the following data sources have been identified, as information of common interest for the whole set of verticals:
  - Meteorology (historical, not forecast).
  - Calendar of holidays and special days (annual calendar with detail by municipalities).
  - Census information (demographic and socioeconomic data).

The architectural structure of the platform is represented in the following image:

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

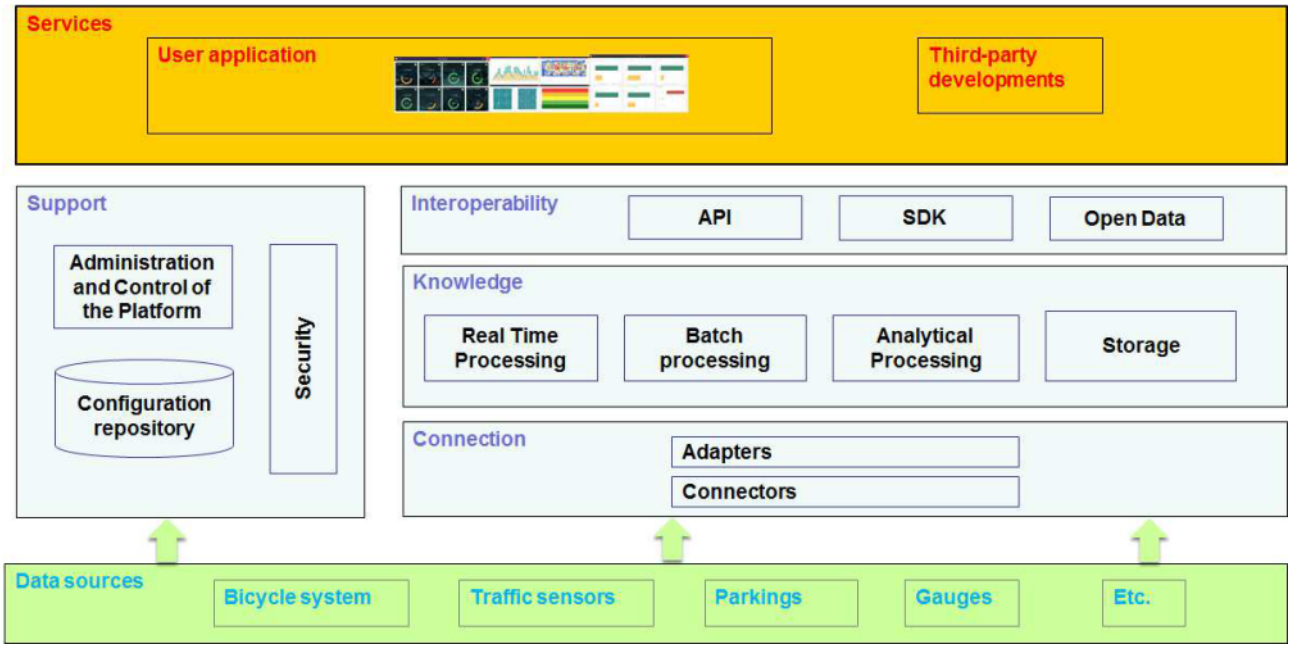


Figure 8.13 – San Sebastian platform architecture

- Systems capture Layer: it is responsible for the collection of information sources that feed the platform (sensors, structured and unstructured information, data flows, etc.) and may include geo-referenced information associated with them.
- Connection Layer: includes components and open source tools that facilitate the aggregation of information from the different data sources being able to work with connected devices through a virtual private network (VPN). The objective of the tools of this layer is not only to provide information to the knowledge layer independently of the devices giving a semantic view of the acquired data, decoupled from the acquisition protocols, but also the management of the devices that they do not have their own operational systems that are already in charge of their management.
- Knowledge layer: it offers the elements of treatment, management and exploitation of the information provided by the data acquisition layer independently of the devices, giving a semantic view of the acquired data and decoupling from the acquisition protocols. On the one hand, this layer includes information persistence tools that will be used depending on the scope (historical, real-time or geo-referenced), the required latency of access to the data or the distribution and scalability of the information of a secure form, including ability to analyse and process large amounts of data. On the other hand, this layer also includes tools for processing the data received from the acquisition layer in real time and Batch, through ETL processes, Machine Learning. Finally, this layer includes tools for the analytical treatment of data through BI tools, such as Dashboard and Reporting tools.
- Interoperability Layer: collects the functionalities corresponding to the tools that allow exposing the functionality of the platform based on services that can be consumed by the Mobility Platform itself or external applications. Exposing the functionality of the platform implies providing standard and open interfaces, based on web service technologies, that guarantee the sending of data by devices and other information environments and access to

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

them by different applications, both in real time as deferred. For this, in this layer there is an API manager that exposes the set of open programming interfaces API (*Application programming interface*) REST to read and act on the information handled, as well as a kit of development tools (Software Development Kit-SDK and APIs) and templates and modules for develop advanced applications and services.

- Smart Services Layer: collects the functionalities corresponding to the applications and business services and/or added value, interacting with the platform through the Interoperability layer. This layer includes the transverse tool of the Integral Control Panel, which is based on the rest of the layers and transversal tools to offer georeferenced visualization features, dashboard, strategic plans, indicators, analytics, reports, event management and administration and configuration.
- Support Layer: allows having a unified control of the operation of the platform. The security module collects the rest of the Capabilities of the Support layer related to security, this is privacy, confidentiality, authorized access, authentication, traceability and security and encryption of stored data and managed by the Mobility Platform, as well as with the management of roles, users and permissions to limit access to information that each user can view according to their profile.

The platform has a web interface through which users can access and manage all the functionalities. To enter the visual interface, users must have a user account and password.

Figure 8.14 – The authentication page of the Mobility platform

The global vision is represented through macro indicators: quantitative measures that are considered key in the functioning of each department. In this way, a card summarizing the value of the macro indicator in real time is associated to each department or scope of action. The content of the information in this first panel serves to provide the most relevant information of each area at a glance, which will be identified by a representative icon and a name.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

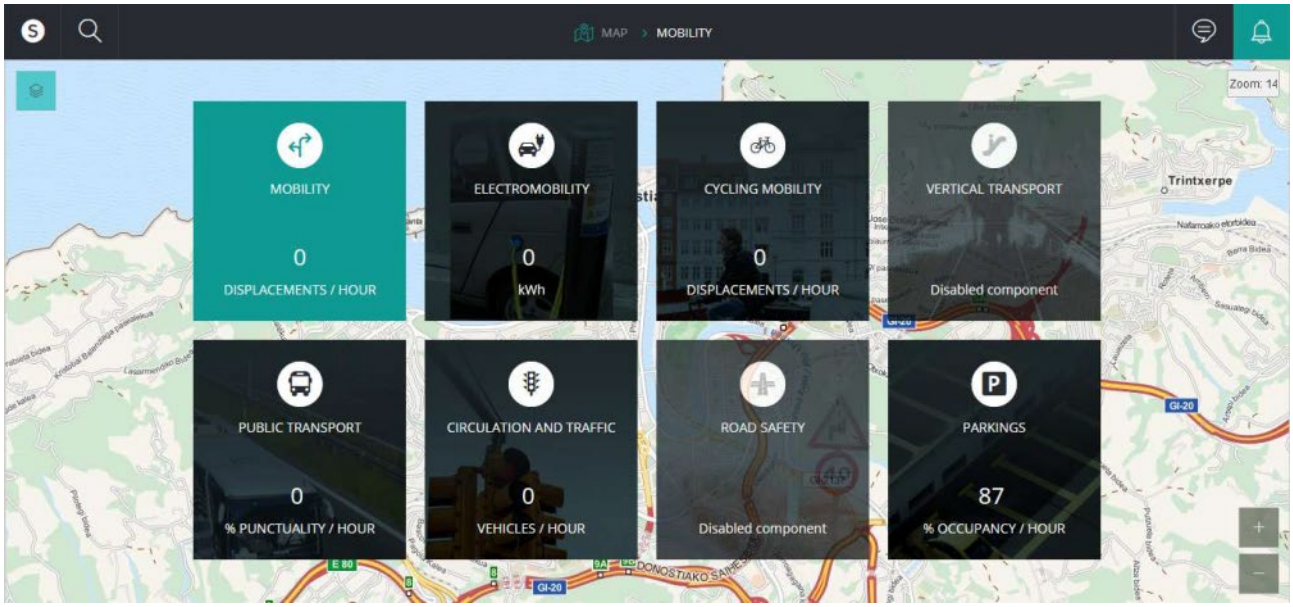


Figure 8.15 – The icons in the Mobility platform

The fundamental objective of the functionality of management and evaluation of indicators (KPIs) is to show the indicators of the different department and of the strategic objectives of the city. The visualization is very flexible, since this section of the tool is designed to allow playing on the different possible dimensions of the data, allowing establishing relationships between the elements of the different indicators such as, for example: number of trips by public bicycle, evolution of the average daily traffic intensity or the availability of parking spaces. To complement this information, the user will have different tools with which to cross information such as, for example, the type of day, temperature, etc. In this way the user can better contextualize the information displayed.

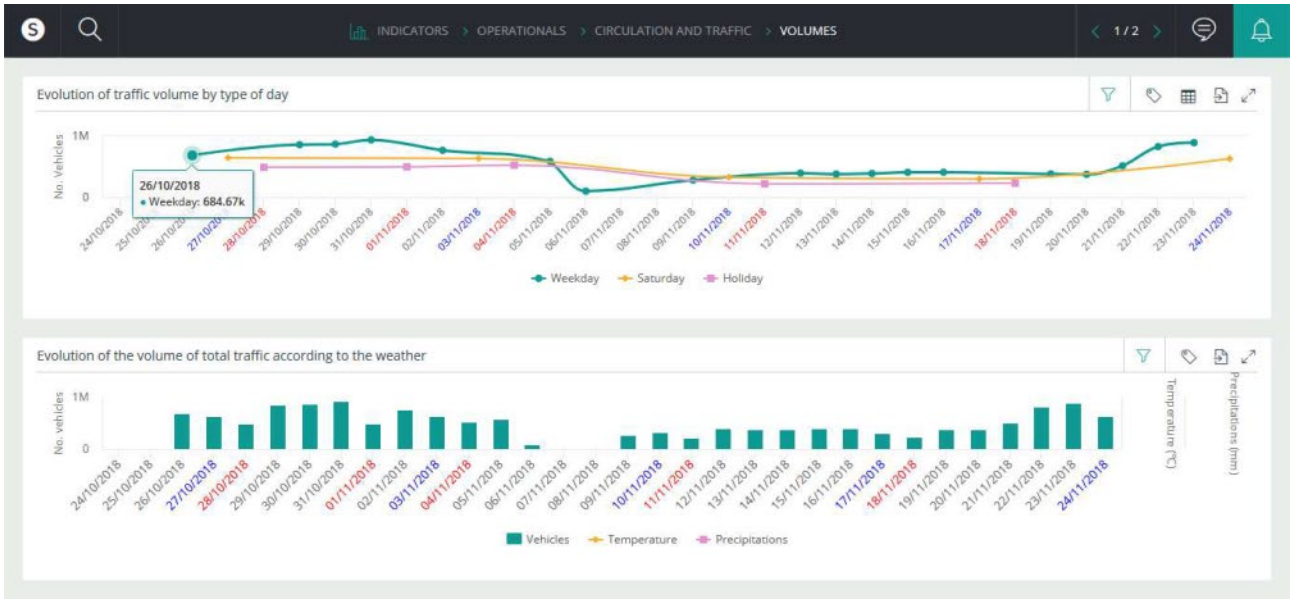


Figure 8.16 – Evolution of traffic volume by type of day and weather conditions

The users have the possibilities to download reports and statistics that can be related to consumption, number of travellers, environmental impact, events, incidents, etc. The reports can be

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

grouped according to different criteria: date or date intervals, periodicity, priorities, geographical areas, or others.

The platform includes an Event Management module too: events (scheduled and unscheduled), incidents and decision support that has the objective of centralizing all the incidents and conditions that occur in the space that is being monitored, integrating information from different data sources and / or systems that may exist. This module provides common capabilities to other services taking into account their particularities and needs, and provides both a partial vision for management, and a global vision to determine the scope of events and incidents by expanding the information with content and capacity geo-referencing of them.

The platform allows the establishment of an action protocol. These protocols are the set of actions that must be performed to solve an event or incidence and will be composed of an ordered sequence of actions that will carry a short description and an estimate of the time in which said action should be performed. These times (which will be configurable), will be used during the event / incident management process to control the time of resolution of the same. An event / incident may have one or no associated action protocol, but never more than one.

Direct impacts

The mobility platform allows the planning authorities improving the quality and the reliability of the mobility services thanks to the information obtained, increase services efficiency reducing operating costs and optimally coordinating resources. Moreover, the Event Management module allows a faster intervention in case of unscheduled events/incidents and a better management of the situation.

The platform elaborates data and makes predictions on the basis of the events/incidents registered and can anticipate problems and future trends.

The services providers can optimize the resources used improving the economic efficiency of their business.

Citizens can benefit of higher quality services and have a real-time information on the transport status.

Indirect impacts

- A better mobility management should suppose an improved route planning to reduce traffic congestion problems, and so that, reduce energy consumptions in all senses.
- An improved quality of the public transport and of the other services related to sharing mobility can increase the number of people that won't use their private vehicle with benefit effects on environment, CO2 emission and quality of urban spaces.
- New platform/system management should demand new job profiles in order to process all the information received from multiple mobility data sources.

Market analysis: enablers and obstacles

Legal framework

UNE 178104 standard of AENOR: Comprehensive systems for a smart city management. Requirements of interoperability for a Smart City Platform.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

The platform interfaces for managers, urban service providers and citizens comply with the W3C accessibility standards, specifically the "Web Content Accessibility Guidelines 2.0" standard that has been in force since 2012. This makes the platform strongly aligned with Directive (EU) 2016/2102.

Incentives

In order to contribute to the achievement of the objectives of the Europe 2020 Strategy, the European Structural and Investment Funds intend to support the Sustainable and Integrated Urban Development. For this, it is necessary to have a coherent, balanced strategy with a long-term vision. In the case of Spain, more than 1,000 million euros have been allocated for the development of these Strategies:

- The DUSI Strategies should be developed in cities or urban functional areas of more than 20,000 inhabitants. The digital transformation and the practical use of data analytics are some of the aspects that will be promoted through these initiatives.

Human factor (success factors, opposed sentiments…)

The developed solution is innovative as it is structured in order to facilitate comprehensive monitoring of all services, management of devices and events, strategy management and decision making related to mobility. The platform combines information available from various data sources, to show information contextualized to the global status of the city and its various departments. In this way, a better coordination of available resources and a clearer visualization of the behaviour patterns of the mobility services can be achieved. Moreover, the platform is user-friendly, easily accessible and usable.

Competitors

Others web platform developers. Another type of competitor may be companies that have a platform for a specific vertical of the city (energy, water, security, etc.) and want to integrate other verticals to give a more global vision of the city.

First scale up analysis:

Lessons learnt

The integration and exploitation of data from urban systems using Business Intelligence and Big Data techniques, provides vital information for an optimal and correct management of municipal services. A platform, extracting and transforming the data captured by the sensors and operational systems of the city and transforming them in information easily consultable and immediate, is a more and more fundamental instrument to plan efficiently mobility related actions.

The platform has to be equipped with technologies that guarantee security of the data, user friendly and easy-to-use.

Optimal scale for next implementations

The Mobility Platform allows easy scaling of services by requiring only a provisioning and configuration process, facilitating the integration of new data sources and services by evolving the solution. The architecture is designed in a modular way so that, without needing to modify the same,

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

it can scale its processing and storage capacity and respond in real time to a greater number of sensors and actuators without affecting its performance.

Regarding replicability, the platform has been designed as a highly replicable solution. The data models created for departments are applicable in other cities and with the integration of the corresponding data provider systems, an instance could be configured for each city. In this context, the horizontal scalability of the platform allows starting the deployment with a certain number of compute nodes and scale up according to the needs that may arise.

Further developments needed

The platform can be easily scaled adding other data sources not directly related to mobility but to other management areas for the municipality. Such as environment, energy, water, etc. In this way, it can provide services to other municipal departments in addition to mobility area.

Expected impacts in the next future

The platform will improve the management of the mobility related services.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Comparison of the different solutions and approaches

Charging infrastructures and e-fleets

The first solution in Florence is very articulated and it is dedicated to the specific needs of a particular fleet such as the taxi service; it involves infrastructural innovation (fast recharge technology, dedicated charging points, integration with the existing network,…), new e-vehicles and management supports (EMM, booking App, discounts and agreements). The charging points in Bristol are the first seed for the deployment of the new infrastructure in the region while the e-bikes measure is aimed at changing people habits from private car fleets to a more active and sustainable transport system.

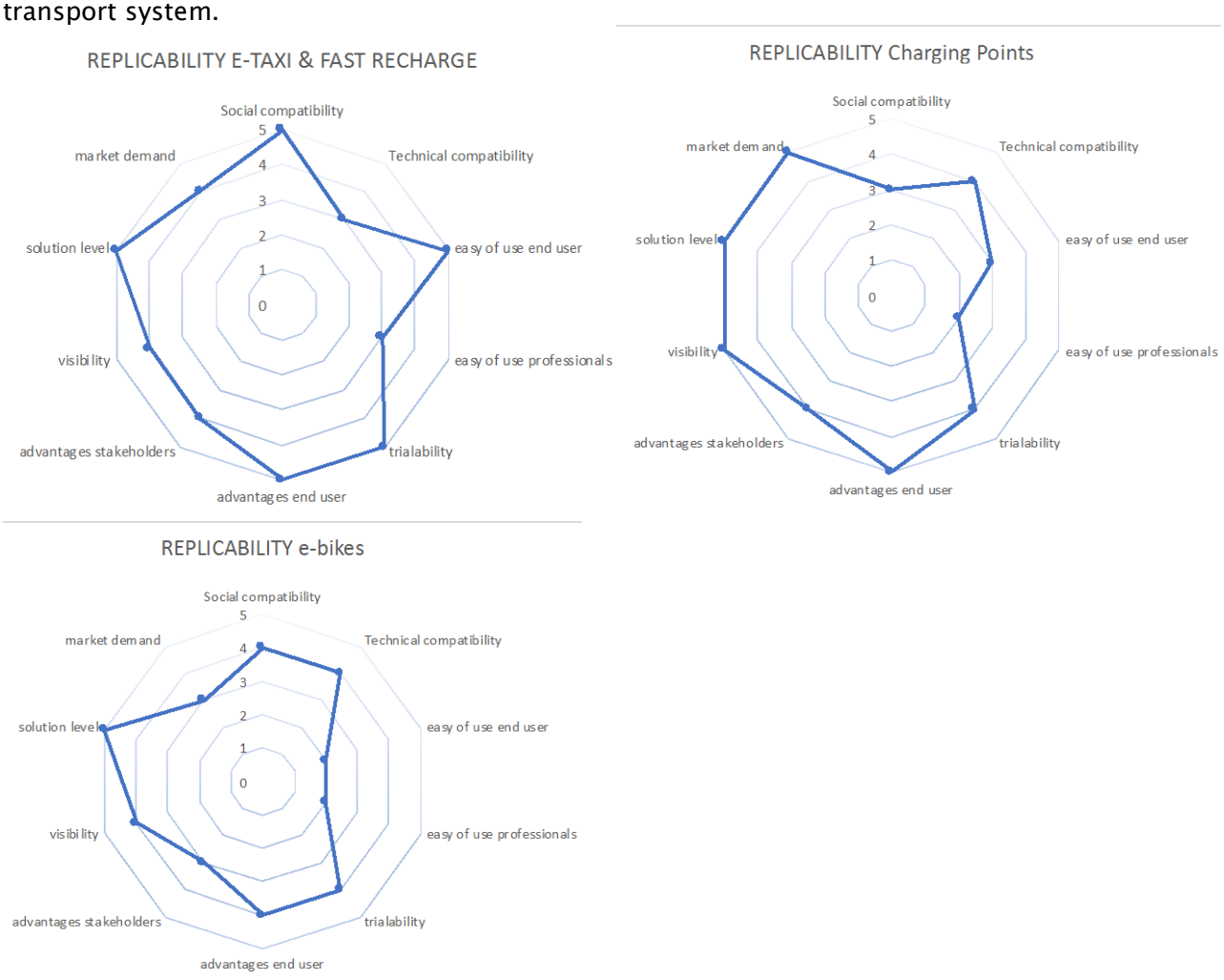


Figure 8.13 comparison among the different solutions about charging infrastructure and e-fleets

The three actions present good profiles with high social compatibility and advantages for users as well as visibility and trialability values. These solutions are trying to solve very common problems to European cities with a great potential for propagation across cities although the market demand in some cases is not yet developed and the user-friendliness must still be improved or supported with trainings.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Mobility supporting solutions

Generally, the three solutions show very high level of replicability being compatible with the existing technology and answering to a common need of smart cities and markets.
They bring a lot of advantages to end users even if, in the case of the platform, the visibility for the general public could be optimised as well as user-friendliness.

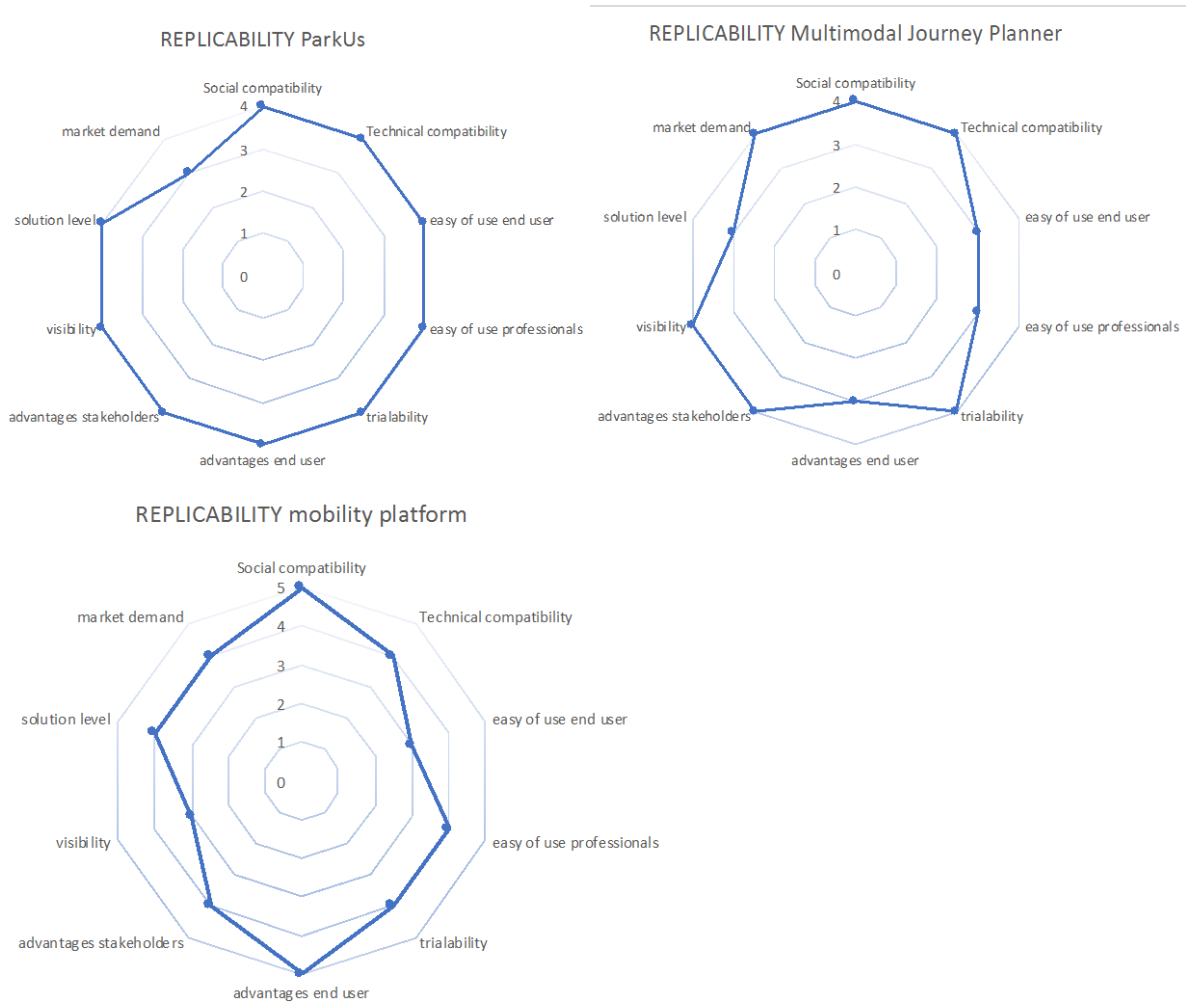


Figure 8.14 comparison among the different solutions supporting smart mobility

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

9. ICT & SMART INFRASTRUCTURES

Starting from infrastructural interventions (mobile network, electric grid, public lighting), this section illustrates the main ICT innovative actions consisting in the different kind of platforms (smart mobility, SCCR, ICT and citizens participation) and the data management.

Solution 1: High speed mobile network based on postWIMAX technology

Main partners involved: Sistelec, Fomento de San Sebastian, ADS (San Sebastian Municipality)

Short description of the action

This intervention aims at installing the best in class of current market provider technology based in the Post-Wimax technology in order to deeply a multipurpose backbone network, completely managed by Fomento de San Sebastian that can deploy several high bandwidth and low latency services like video surveillance, digital voice calls. The improvement between the previous wireless technologies and this high-speed mobile network, will be the scope and its bandwidth: it offers transfer rates of 250 Mbps over distances up to 30 km from a base station. The main features of the network are:

- High bandwidth
- Latency < 7ms
- Easy to deploy
- Complementary with other solutions (WiFi)
- Great performance
- Coverage (Los, nLos and NLos)
- Multi-purpose network

Sistelec, in collaboration with Fomento San Sebastian, had carried out coverage studies in order to select the best sites possible to implement the postWIMAX technology and also the backbone communications with maximum resilience in the Urumea area, interconnecting also wireless and fibre. Thanks to the project is an improvement of the network, from the 25% of coverage to a %75. This helps to increase the capacity of the network and include more quality services around the city.

Figure 9.1 – Location of the URUMEA district related with San Sebastian City

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Value proposition

The main purpose of the project is to provide a future proof backhaul platform that will be able to provide several and very different services from the lighthouse cities to the final users such as citizens, small business and other services providers.

The project wants to provide a wide access to both municipality services but also to other project partners in order to get a transparent network through high speed broadband wireless network. So other municipality services and also third party could be deployed, quickly, without incurring new costs and in an easy way. No adaptors are needed except an RJ45 Ethernet standard connectivity.

Technology

WiMAX (Worldwide Interoperability for Microwave Access) is a family of wireless communications standards initially designed to provide 30 to 40 megabit-per-second data rates, with the 2011 update providing up to 1 Gbit/s for fixed stations.

Post WiMAX is the named commonly used to describe the new technologies that some providers use to evolve from a WiMAX standard to a commonly proprietary platform solution.

Feature	Post WIMAX	802.16 (WIMAX standard)
Throughput	>= 250Mbps	Up to 140Mbps (4 radios)
Latency	5~ 7 ms	10~40 ms
Channel Bandwidth	40 /20/ 10/ 5 MHz	10 / 7 / 5 / 3.5 / 1.75 MHz
Multi Band	4900 - 5925 MHz	4900-5875MHz
Max users/Sector	238	50
MIMO	MIMO 2x2	SISO
Spectral Efficiency	6bps/Hz	3.5bps/Hz
Remote Management	Web access by HTTP and HTTPS/TLS NMS by SNMP	Web, SSH, XML-RPL, SNMP v1, 2 y 3

Figure 9.2 – Post WIMAX features vs WIMAX standard features

Sistelec selected Cambium as the technology provider and the 450i platform as the product to deploy in the Project as it has a Simple Network Design, intuitive and efficient, has high performance, offers security with over-the-air DES (Data Encryption Standard) encryption or AES (Advanced Encryption Standard) capabilities. Cambium wireless access network solutions offer a high level of tolerance to self-interference is easy scalable: the system was designed to maximize the ability to scale as the network grows, and not suffer any performance degradation.

The platform can be configured as a single-site point-to-multipoint system that supports subscribers for distances up to 40 miles (64 kilometres). In addition, the system includes; interfaces

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

that enable it to easily integrate with standard network management tools. as well as diagnostic capabilities needed to remotely monitor the network.

PMP 450i platform can enable lighthouses to deliver high performance, reliable, and profitable services that supply customer and user demands for more and faster communications. The PMP 450 offers several key advantages to help these organizations achieve their connectivity objectives,

Cambium technology offers moreover continuous development of new solutions the will carry out a much better radio performance and a continuous evolution of the product during the project development. Most of the improvements are only software based, so with a simple firmware upgrade the new features could be applied on an existing deployment.

The PMP 450i boasts a great spectral efficiency due to system architecture choices and superior radio design. By combining optimized antenna design, advanced RF radio architecture, and GPS Synchronization, the PMP 450i can re-use the same frequency across the network and does not require any guard band (or unused "fallow" frequency) between adjacent channels to do so.

Once selected the technology Sistelec, with FSS collaboration, designed the Wireless broadband network.

In order to ensure the network reliability, Sistelec according with FSS has designed a ring topology that ensures that in case of any device or link failure, there is another path to reach a fibre point interconnection.

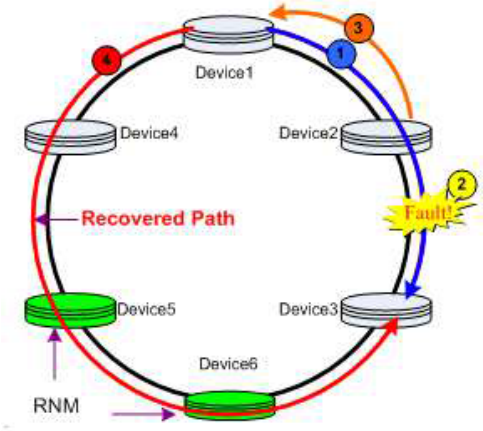


Figure 9.3 – Ring topology link fault

In the following step, Sistelec and FSS detected the sites that have to provide connectivity to the municipality fibre points, and in place where there is no possibility of that, to provide a ring topology that interconnects those points with the fibre points.

Followed the hub selection phase, whose aim was to provide as much coverage as possible with the minimum access points. So, in order to provide the desired coverage and after the backbone site selection Sistelec has collaborated with FSS to finally select the Hub points in which devices AP 450i provide broadband wireless coverage (UBA, Gudamendi, Torre Vodafone, Urgull, Ulia, Estación Tomasene)

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Figure 9.4 – Estimated coverage of the hub selection

Once chosen the technology and detected the Hubs, the next step has been the technical installation (in the following pictures the antenna and the installation in Gudamundi).

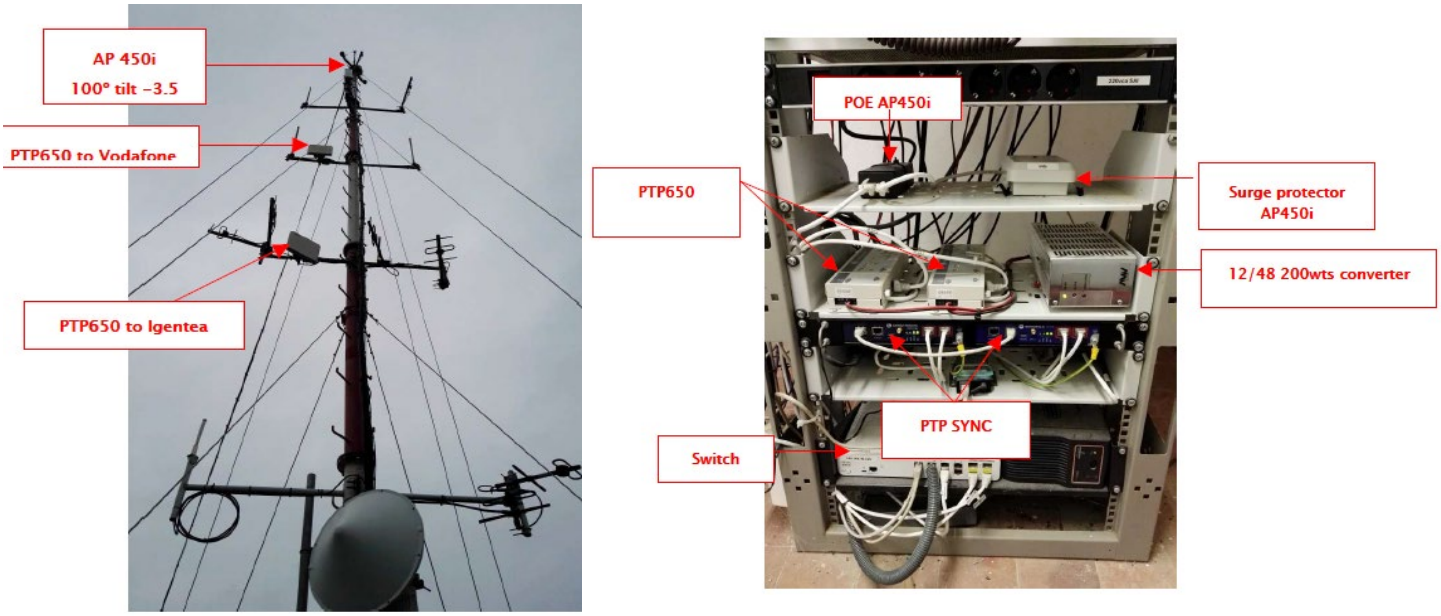


Figure 9.5 – The Gudamundi Antenna, devices and cabinet installation

Innovation Level:

The use of a Post Wimax technology was determined by the specific orography of San Sebastian, in which there are hills at a maximum 250 meters high, (Gudamendi), or 164 meters high, Ulia mountain, that lets a great coverage if there is a use of strategic sites to deploy the service. Thus, makes high speed broadband wireless network the ideal solution to generate a total coverage model that could be useful to deploy IoT and M2M services, like immovable devices and mobile sensors.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Direct impacts

The deployment of the broadband wireless network to other areas without coverage and of actual post WiMAX deployment has allowed access to Urumea, an area where, due to its morphologic characteristics, installing fibre optic or another wire communication service makes was almost impossible, due the extremely high cost.

Indirect impacts

The project expanded the postWIMAX network making a cross attending to northsouth and east-west axis of the city (Boulevard-Easo-Pio XII-Anoeta-Hospitales), where new services with special connectivity needs were launched successfully.

Market analysis: enablers and obstacles

Legal framework

Below is a list of the main regulations that apply to the high-speed network project:

- EN 301 893 V1.7.1 (5.4 GHz)
- EN 302 502 V1.2.1 (5.8 GHz)
- EN 302 326-2 V1.2.2 (3 Ghz)
- EN 302 326-3 V1.3.1 (3 Ghz)
- CE Marked
- R&TTE Directive 1995/5/EC (health)
- Low Voltage Directive 72/23/EEC

Technologies used are committed to meeting the requirements of the European Union (EU) Waste Electrical and Electronic Equipment (WEEE) Directive. This Directive requires producers of electrical and electronic equipment to finance the take back, for reuse or recycling, of their products placed on the EU market after August 13, 2005.

Incentives

None

Human factor (success factors, opposed sentiments,…)

The success factors identified are the following:

- Own municipality network. Thus, allows to complete control of the network facilitating for instance the priority of traffic and some services against others, reduce the dependency from a network operator, and in the unlikely event that something goes wrong within the city, there is always the possibility to control (reconfigure or reuse services) or to add new deploys in a very short time.
- Services in places without any other way of communication. Sometimes because the orography or because it is very complicated to install a wired connection.
- Quick deployment of new services.
- Really easy to integrate service within the municipality network.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

A complete re-engineering process was required to design the new sites and coverage and evolve the current network to provide the backbone connectivity and coverage to provide Urumea district with a broadband transparent wireless network.

Competitors

The main competitors are other companies RADWIN, PROXIM, ZTE (LTE), Huawei (LTE)

First scale up analysis:

Lessons learnt

- Compatible technologies and complementary communications to ensure robustness and redundancy.
- Maximize the ability to provide coverage in places of difficult access, but with quality of service.
- Designing, measure, feedback methodology is needed and mandatory, always there are differences from theory to practice that in a feedback process could be solved step by step.
- The background of the different partners was very important in order to reduce the engineering analysis. However, in this project there were more than fifteen iterations between partners to finally get a ready to deploy project.

Optimal scale for next implementations

Any scale is possible. New base stations can be installed in other locations and connected to the existing network, extending the coverage.
Moreover, the same solution can be applied to other municipalities in the region and then be linked together to create an inter-municipal radio network.

Further developments needed

Future developments will require an upgrade and maintenance of the equipment to new technologies that may arise, that allows better transmission rates or new functionalities.
In addition, more subscribers are being added to the network, extending the benefits of the network to the final users. Future expansions are also under the Municipality study.

Expected impacts in the next future

All the radio network is already installed and ready for operation. Some services are now using the radio network as its backbone transmission network and more subscribers are likely to be added. The radio network will boost the installation of cameras, sensors and wireless access points in the city. In fact, there is currently an ongoing project in "Poligono 27" to provide new services which lies on the radio network.
The network is also a key element for the IoT deployment in the city as it allows to easily install a sensor everywhere under the coverage, without the need of hiring operator services or undertaking the civil works to reach the sensor with a communication cable.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Solution 2: Smart & Resilient Grid

Main partners involved: e-distribuzione

Short description of the action

The electricity grid is capillary in the district and it is managed by e-distribuzione, the Distribution System Operator. The consistence of electricity distribution network in the Municipality of Florence is: 5 HV/LV (Primary) Substations and 487 MV/LV(Secondary) Substations.
In a sub set of Primary (HV/MV) Substations (n.2) and Secondary (MV/LV) Substations (n.60) (around 25.000 LV customers) of the Pilot area of Florence, e-distribuzione will install several innovative devices to upgrade the existing grid into a smart one, enabling remote control and advanced automation.
The Smart Grids implementation involves about 25.000 LV citizens enabling also innovative services for citizens, like customer awareness, that e-distribuzione will enhance through the distribution of smart info kit to 600 families, selected by the Municipality of Florence.
e-distribuzione, the Distribution System Operator, has implemented Smart Grids measures focused on innovative solutions that make possible advanced functionalities for: the remote monitoring and control of equipment in HV/MV and MV/LV substations; the implementation of advanced automation functionalities to reduce the outages of network; improving the quality of service for citizens.
The collaboration between DSO and the municipality is playing an important role in terms of area and priorities definitions in the Municipality's planning tools, gathering data in the Smart City Control Room about the quality of the service.

Value proposition

The new technologies have improved the grid performances in terms of reliability, resilience, quality of service. In addition, the Smart Grids allow enabling new innovative services for citizens (data access, RES connection, EV recharge).

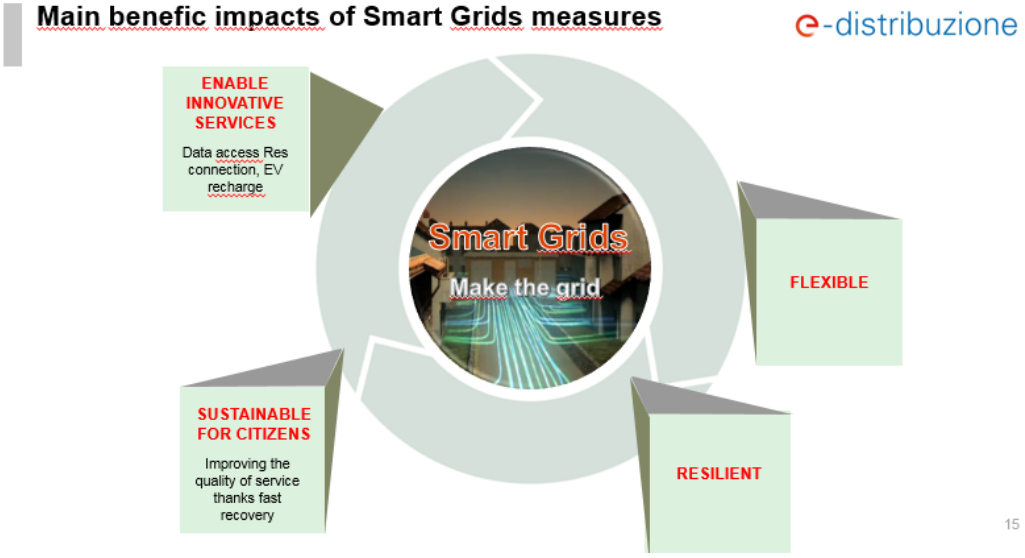


Figure 9.6 – impacts of smart grid measures

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Technology

The e-distribuzione's solution to make electricity infrastructures resilient are:
- Increasing of infrastructure capacity to withstand unpredictable events (floods, fires, heat waves, etc) by developing of new engineering designs and management strategies, such as measures of remote control and automation of the electricity distribution network, allowing to empower the existing grid as "Smart Grid".
- Necessity to improve the continuity of service performances of the distribution network toward the LV and MV customers allowing the investigation and development of a new technique of network automation. This innovative selection system of grid fault relies on the availability of a short-latency communication carrier in conjunction with a series of high-performance devices.

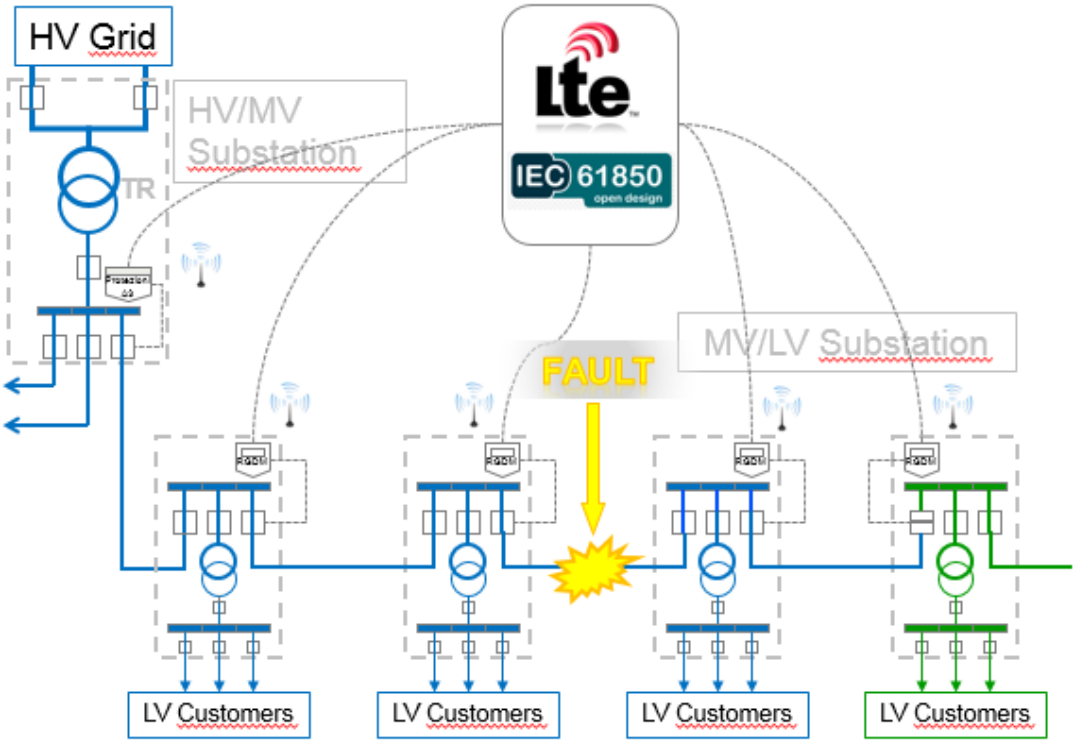


Figure 9.7 – the innovative selection system of grid faults

-Enabling, through "Smart Grids" measures (customer awareness devices), of innovative services for citizens, fostering energy efficiency solutions, sustainable electric mobility, with the aim to answer to the stresses of the environment in the long run, creating a resilient city.

The resiliency of infrastructure at system level depends on planning requirement such as a high level of remote control and automation to reduce time of intervention.
According to the aim, e-distribuzione has been setting the implementation of Smart Grids functionalities in the Pilot area of Florence (consisting of on 2 HV/MV primary substations and 60 MV/LV secondary substations) focused on the application of innovative power equipment and

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

telecommunication devices and the installation of sensors and actuators enabling the remote control and automation of the distribution network.

The e-distribuzione plan included:

- Remote monitoring and control of MV network through the installation of new "smart" devices to implement advanced automation functionalities, reducing the outages of network, improving efficiency of electric system and the quality of services for citizens. Among these may be the upgrading of primary and secondary substations with more efficient "Smart" devices:
  - TPT2020, new protection system for evolved remote control (DV 7500 to be installed in 2 Primary Substations), device for monitoring of MV energy flows, in order to increase the hosting capacity of the grids for RES integration, ensuring the security and reliability of the electric system
  - innovative automatic fault detectors on MV lines integrated in the remote-control system (RGDM, Smart Termination to be installed in 60 Secondary Substation), to improve the quality of service.
  - TLC equipment (including designing and implementation of data transmission network solution for remote control and automation functions) to connect network assets in a "Always on mode" to allow the remote control in HV/MV and MV/LV substations.
- Remote monitoring and control of LV network through the installation of new devices in secondary substation (remote controlled breakers) aiming to improve the quality of service (it will involve almost 60 secondary substation)
- Replacement of conventional network equipment with innovative solutions (power panel DY900) to increase the reliability of the grids also in case of emergency such as floods

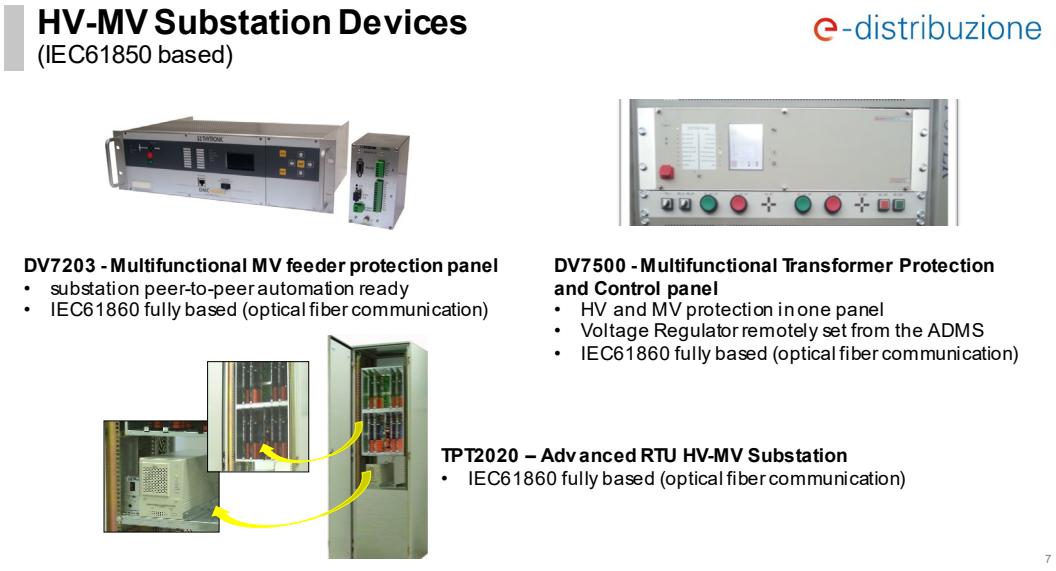


Figure 9.8 – High/Medium Voltage Substation devices

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

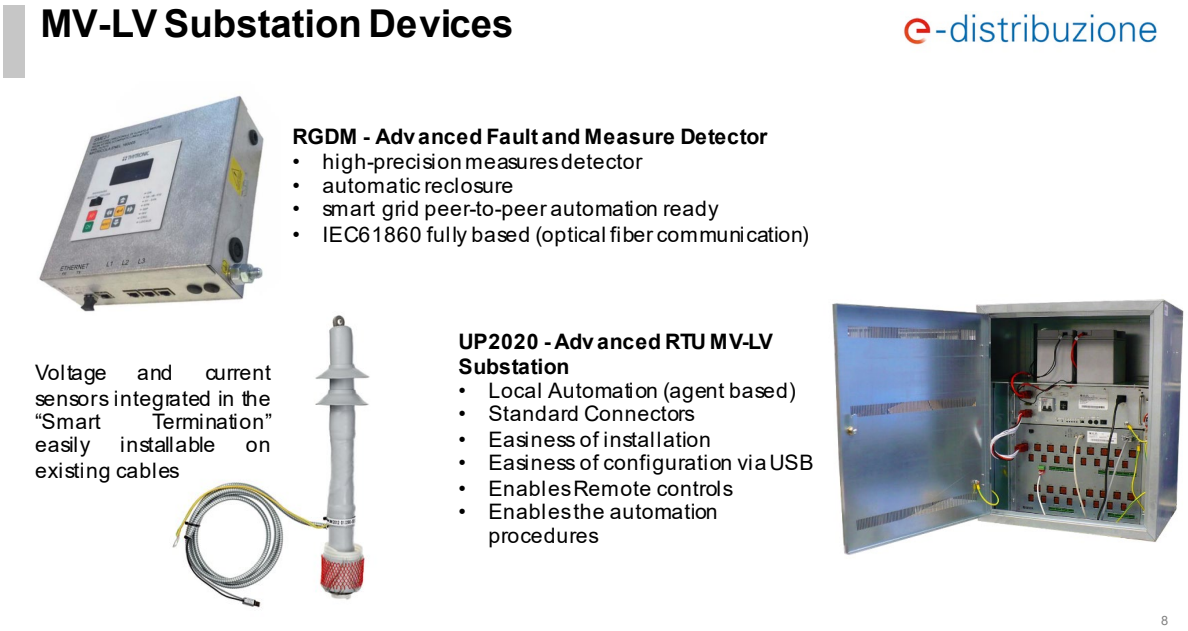


Figure 9.9 – Medium/Low Voltage substation devices

Innovation level:

According to the Call SCC1, the e-distribuzione innovation level of its technology is referred to a TRL 7 action

Main impacts of the measure (economical, environmental, social)

The grid empowered by e-distribuzione is more flexible, resilient and sustainable for citizens through a better quality of service. In addition the Smart Grids allow to enable new innovative services for citizens (data access, RES connection, EV recharge)

Direct impact:

The remote control technology implemented in the project by e-distribuzione allows the reduction of interruption measured by SAIFI (Number of short and long interruptions per LV customer) and SAIDI (long interruptions duration per LV customer) index

Indirect impact:

Many other actions will benefit from this measure: the data availability will influence user's behaviour (energy demand) and will allow detailed analysis and efficiency programs (ICT platform, buildings retrofitting); the distributed production of electricity will be supported (CHP & RES) as well as e-mobility implementation.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

	Actions	Functionalities	Benefits
SMART GRID	Network automation and control systems and Centralized and distributed intelligence e.g.: Measures on Primary and Secondary Substations (e. g. TPT 2020 install, new protection system for evolved remote management, implementation of closed configuration of network, fault detectors.) Communication Network elements connected with technologies "always on" (Secondary Substations)	✓ Voltage Control on the MV network in real time ✓ LV network monitoring and control ✓ Increasing "Hosting Capacity" ✓ Automatic functionality of fault research on MV lines ✓ Communication system "always on"	✓ Increasing of security and quality of electric system in presence of distributed generation (DG) ✓ Increasing efficiency of electric system ✓ Resilience of electric distribution network ✓ Enable "Smart" functionalities within power grid ✓ Create "interoperability" among different infrastructures
Services enabled by SMART GRID	Smart Info (customer awareness)	✓ Customers awareness about electricity consumption	✓ Reduction of CO2 emissions ✓ Lower cost of bill
	Development of mobility through Installation of Recharging infrastructures fully integrated in the grid in smart way	✓ Enabling electric vehicles of taxi fleet	✓ Electric mobility development, reduction of CO2 emissions

Market analysis: enablers and obstacles

Competitors

There are no competitors (e-distribuzione is the distribution system operator with exclusive granting of distribution network management in the Municipality of Florence) but other DSOs in other regions who could be considered a market benchmark.

Legal framework & incentives

Up to now no facilitations or economic incentives for e-distribuzione but at national level there are mandatory thresholds for the service quality performances (Integrated text of output-based adjustment of distribution and measurement of electricity- Annex A to AEEGSI Resolution 646/2015/R/eel) and bilateral agreements with the local authorities.

Human factor (success factors, opposed sentiments,…)

Increased efficiency, resilience as reduction of time of electric interruption improving the quality of electric service thanks fast recovery of service.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

First scale up analysis

Lessons learnt

the cost is the main barrier for the implementation, but if the action is included in a planning tool as enabler (for RES, e-mobility, users awareness, active demand management,…) it could be easily deployed. The technology is improving faster and faster and this aspect must be taken into account while designing the extensions (from the proposal phase to the implementation an update of the technology foreseen has been needed).

Optimal scale for next implementations

At least urban scale, but it can be extended at national level

Further developments needed

More information for users and service providers (active demand managers, prosumers,..) could enhance and accelerate the exploitation of the new opportunities offered by the updated grid.

Expected impacts

The smart grid is the key to develop further smart services

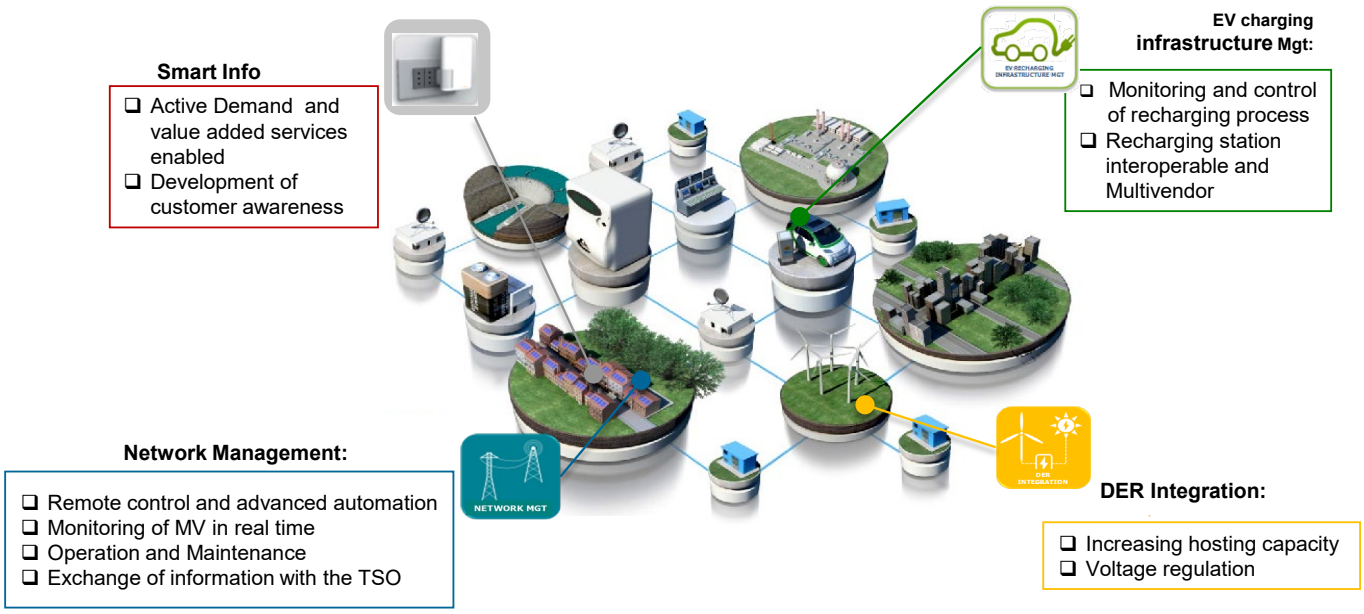


Figure 9.10 –Smart Grid impacts

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Solution 3: Smart public lighting

Main partners involved: Leycolan, Fomento San Sebastián, ADS (San Sebastian Municipality)

Short description of the action

The City of San Sebastian counts with over 30.000 Street light points. The street light infrastructure is partially using old conventional technology, i.e. HPSV light generation (High Pressure Sodium Vapour).
In the latest years, the city of San Sebastian has also started the substitution of those conventional lamps with LED lamps.
In the Replicate framework, an innovative lighting system has been implemented. The interventions consist of:

- Replacement of 90 vapour-sodium luminaries with new LED technology implemented. (60% of the existing lighting spots in the area).
- Innovative systems: 19 detection devices, 2 audio packs, each of six units, 2 video transmitting devices, 1 vehicle counter, 2 energy meter devices, 2 rain sensors and one vehicle counter

Value proposition

The public lighting service has to become more efficient to reduce the energy consumption and consequent CO_2 emissions. Above the energy efficiency issue, the infrastructure, can be optimised carrying other services on board (Implementation of a remote / Management Control system, implementation of light, rain and presence detection devices, implementation of several IP services, Vehicle counting, Sonorization, video detections and image transmission devices).

Technology

The proposal consisted on:

A. LIGHTING AND LIGHTING SYSTEM:

The project proposal consisted, finally, on substituting the whole 90 lampposts of the area covered by 2 cabinets. (Initially the project contemplated 142 lampposts, but after a deeper analysis, it was considered much better to implement the project over 90 lampposts and only 2 cabinets). These lampposts consisting in HPSV lamps of 250W and 150 W, where proposed to be substituted by LED lamps, in 2 different models or LED technologies:

i. 52 conventional lamps of 250W to be substituted by 52 LED lamps from Philips brand (SMD Led Modules) of 120 W and 100 W.
ii. 38 conventional lamps of 150W to be substituted by 38 LED lamps SULKA Model with LED COB Technology (1 LED – Citizen Brand) of 100 W.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

In addition, the proposal includes the installation of an intelligent and remote-control system of the street lights, controlling point to point, with the target of having the capability of controlling every single light point, monitor the energy consumption, manage calendars, regulation (DIM) of the lights according to the real needs of the environment, and the presence of cars and persons.

B. INNOVATIVE SERVICES POSSIBLE TO IMPLEMENT USING THE EXISTING INFRASTRUCTURE OF THE PUBLIC LIGHTING (EXISTING POWER/ENERGY WIRES).

The proposal consists on implementing just one "control Node" in every lamppost or point/service to be controlled, and just 1 head end or concentrator at every control cabinet of each circuit. The communication for these services is carried through the existing Power line for the supply of energy to the lampposts. Therefore, it is not needed to incur in additional and expensive road works, or deployment of new wiring for implementing these services of light management and/or new services.

With this thinking the proposal consists on implementing a remote-control system for the 90 Lampposts, having 2 central cabinets: 1 providing the power and control to 52 lamps, and the second one providing the power and control to 38 lampposts.

To have the control of every lampposts, in every lamp will be installed 1 control Node for the intelligent lighting system (It is incorporated into the pole) and to make it more intelligent, it is proposed to implement specific detection systems, in some of the posts, making a maximum coverage of the detection areas in order to provide maximum security and effectivity when providing light in all cases that there is presence in the area. The proposal includes the installation of 4 detection Radars (Wide angle detection radars that will manage the light regulation according to the presence of persons or vehicles), and 12 vision detection cameras. The aim of these presence detectors is to provide the adequate lighting to the passing by people or cars.

In addition to the intelligent lighting control system, it is proposed to implement different IP services, taking advantage that with the installation of the head ends and the control nodes; it is created a LAN over the power grid covering the street light installation grid. The proposal includes:

- IP audio services (6 units of 2 loIP),
- 4 IP vision cameras (2 for the Municipality police, and 2 for Streaming viewing cameras),
- 2 rain sensors,
- 1 vehicle counter
- 2 energy meters.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

SMD- Led modules from Philips

SULKA LED COB lights

SMD- Led modules from Philips

SULKA LED COB lights

Figure 9.11 – different LED lights implemented

Lampposts with Audio IP, and Domo video IP

Figure 9.12 – new smart lampposts

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Figure 9.13 – Pictures by the detection device

Innovation

With all the IP devices, it is possible to control, or get knowledge and information about the street lighting service status, about its performance, on real time, at every moment. It is possible to regulate the lights or modify the regulations. It is possible to act on the sound system and give notices/advertisings, or evacuation notices, for example. Data can be stores, from the vehicle count that are coming into this area or leaving the area of the project.

The modified infrastructure with this technology, can perform these services, but additionally as it has been created a LAN network over the Power line, is also possible to incorporate other IP services that could come later, just with the connection of any device to the created LAN network.

Direct impacts

- The action will reduce the energy consumption of the public lighting network (and the GHG emissions) and the related costs. The reduction in kWh consumption comparing same months has been of 69%.
- Reduction of maintenance cost in the coming years, due to a longer products lifetime, and the maintenance works as a result of the system alerting on the installation issues or problems by remote control, previous to needing a physical visit to the site.
- Increased safeness in the district: a huge amount of data could be made available to the municipal control room to increase and manage the safety and vigilance of the area
- Optimized impact of the services infrastructures: the impact of other infrastructures (WiFi network, video surveillance, traffic & access control, ...) minimized while their coverage will be widened.

Indirect impacts

- Capacity building and jobs

Market analysis: enablers and obstacles

Legal framework

The regulation to comply with is related to the Spanish Law for the Street light Regulation RD 1890/2008, including technical instructions (ITC-EA-01 Y ITC-EA-02). Additionally for all the IP services and remote control the regulations to comply with are the Regulations related to the Electrical power Grid regulations in Medium and Low Voltage: RD 842/2002 and its ITC-BT-09.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Incentives

None

Human factor (success factors, opposed sentiments, …)

Lights and light control system will be 100% replicable, together with the detection systems. It can be stated that due to the actual results that are being obtained, - total online control of the installation and energy consumption savings, plus the relatively easy installation procedures, a total replicable project is foreseen in other areas of the city and/or in other cities.
Obstacles: Difficulties in the evaluation of cost savings of the IP service implementation and live conditions improvement generated.

Competitors

The remote control and specifically the long-range detection systems deployed are totally outstanding from what is existing in the market; therefore to bring a more advanced technology to the street light management. The system is built under Open Source programming and is easily integrated in other upper or bigger platforms, while the remote control online to every single point is also an important differential characteristic of the system. Therefore the competitors in the market reaching this level of technology are few.

First scale up analysis:

Lessons learnt

For the successful implementation of the project, a key factor has been the deep knowledge on street light remote control system. And the open source system able to integrate in all other systems.

Actions to be implemented and time for resolving or conducting the administrative procedures must be considered in all cases, as they may interfere deeply on the time planning of the projects.

The collaterals, and other key or less key but still affected holders or entities (people) must be taken in consideration beforehand, in order to avoid time losses and/or cost deviations.

Optimal scale for next implementations

In terms of scalability, the project is highly replicable. In San Sebastian there is replication potential for the implementation of the Smart Lighting project model, instruments and results.

Expected impacts in the next future

The installation is expected to improve the results achieved in terms of energy consumption, and if possible, additional IP services will be implemented.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Solution 4: Eco-lighting & smart services

Main partners involved: Silfi, City of Florence

Short description of the action

In Florence there are 40.500 lampposts and 3.500 traffic lights; in the district there are about 7.500 lampposts which are not networked or efficient. Only in the Cascine park during last three years a pilot action has been implemented to test an adaptive light system in a special environment as an urban park.
The municipality is implementing a tailored refurbishment plan of the public lighting infrastructure in the district trying to match for each area the best lighting conditions and the needed additional services (video surveillance, traffic control, WiFi, weather pluvial or wind sensors....).
The video surveillance system in Florence is made of more than 600 cameras (IP cam) connected by 220 km of fiber to manage their data flow.
In Replicate, Silfi is implementing three different smart services exploiting public lighting infrastructure:

- more efficient public lighting
- light surveillance (to watch on sensible targets like IoT installations) and security,
- traffic access control.

Value proposition

The public lighting service has to become more efficient to reduce the energy consumption and consequent CO2 emissions. Above the energy efficiency issue, the infrastructure, can be optimised carrying other services on board (Implementation of a remote / Management Control system, implementation of light, rain and presence detection devices, implementation of several IP services, Vehicle counting, Sonorization, video detections and image transmission devices).
The "Intelligence video analytics on board" based video surveillance systems allow the improvement of the security level and a faster response time for corrective actions on traffic control and security.
The smart development of these systems can be made in two main ways: integrated in the public lighting infrastructure with costs and land use savings or stand alone.

Technology

The solution in use:

The new lighting poles are equipped with LED technology and a standard socket for the integration of ICT devices. The Replicate pilot action has been deployed into two different modalities described below.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

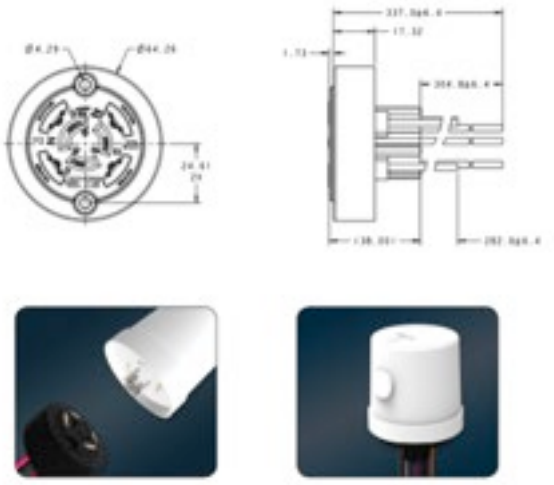


Figure 9.14 – Socket NEMA standard on Led luminaires of Florence

Figure 9.15 – Smart lighting in Florence

A. Integrated systems into city's public lighting

To this modality belong the adaptive lighting system which integrates the fiber optic cameras with the LED lighting on a pedestrian path in the Cascine park.
The system works as follows:
the lights are activated by alarms of specific smart actuators (PLCs) that, interacting with the system of video cameras, allow the introduction of adaptive lighting, characterized by high environmental sustainability criteria according to which light activates with different luminous intensities in real time following the actual use of the paths: in pedestrian areas (parks) the adaptive lighting has been adopted in 70 lighting spots and 25 cameras have been placed.
The system with which the LED light sources, placed inside the luminaire can be individually controlled and managed remotely, enables you to split the road sections areas, groups or individual items for which you can program ignition and lighting levels in function of the contingent necessities.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

In addition to this, in Replicate an access control system into the park has been integrated: the intervention consists in the regulation of the vehicles accesses and the traffic in the Cascine park exploiting the public lighting infrastructure.
The interaction between public lighting and access control system is made by the integrated assets system "video cameras – lights" which allows a significant increase of security levels and smarter control.
The system is made of an entering door equipped with a camera which reads the vehicles licence plates, a laser camera controlling flows and a high efficiency lighting pole to increase visibility in the access area.

The process works as follow:

- The laser camera registers and classifies the vehicles passing through the access point;
- The radio frequency system registers the presence of the "telepass" device on board
- The logic of the systems verifies the login credential of the vehicle telepass
- If the telepass credentials are invalid, the camera reads the vehicle licence plate
- The logic verifies the credential on the basis of the licence plate.

Figure 9.16 – access door to the Cascine park with integration of public lighting, info pannel, video camera and laser camera.

B. Systems integrated with public lighting and traffic lights

These systems were placed on public lighting poles in the north-west area of Florence, and 30 IP cameras were set up in 17 different sites, characterized by metadata detection in relation to the analysis of video streams, through detailed settings provided by the operator (Intelligence video analytics on board).
These cameras allow detailed data analysis. The types of analysis being developed are listed below:
- Count pedestrian flows in predefined directions

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

- Abnormal movements and behaviours of people (e.g. presence of panic)
- Presence of persons in a closed area
- Vehicle counting
- Check for presence of parked vehicles on tram tracks
- Parked vehicles control in the driving lane (double row or traffic block)
- Checking the passage of public buses

The result of the video analysis is a flow of metadata from which it is possible to generate statistical reports, real-time alarms and implementation of traffic regulation systems.

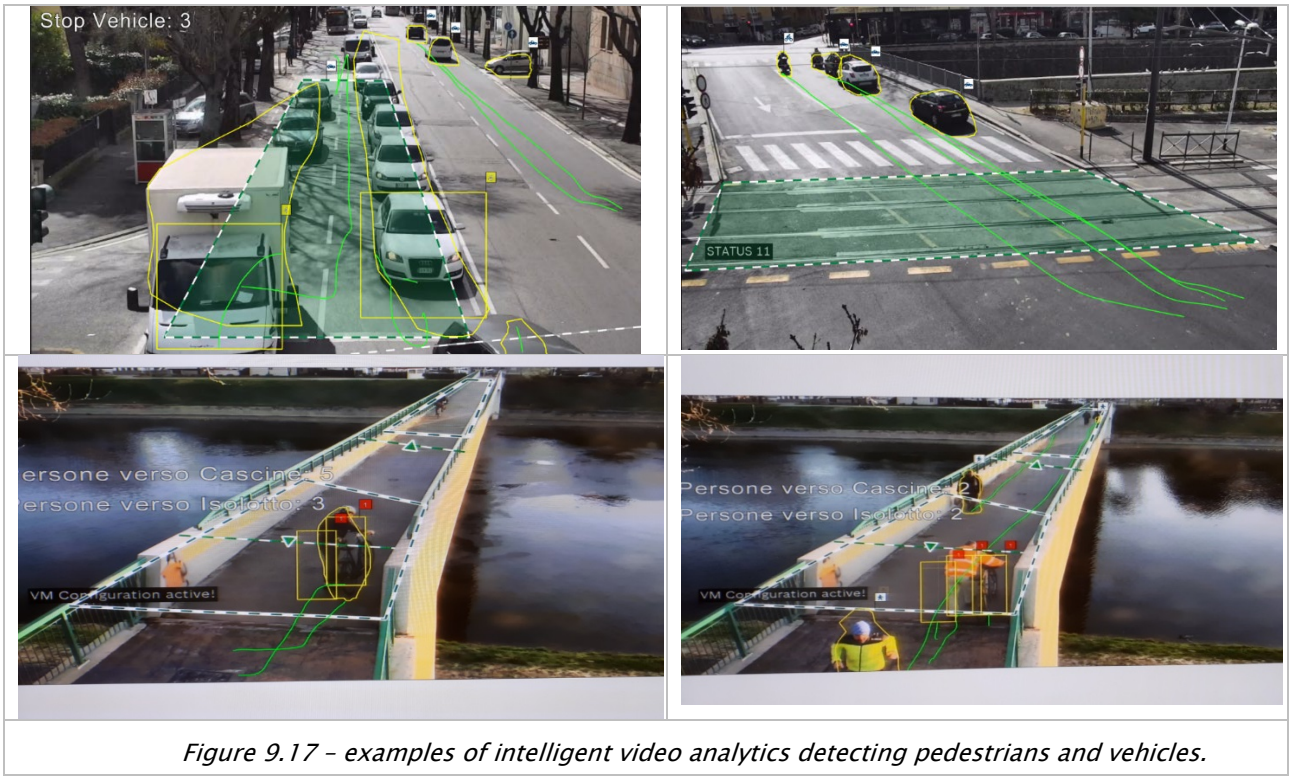


Figure 9.17 – examples of intelligent video analytics detecting pedestrians and vehicles.

Enablers and obstacles

Legal framework:

The municipality of Florence in its sustainable Planning tools (SEAP, Smart city Plan,…) has set efficiency targets for the public lighting service: -15% at 2020 (SEAP) and -40% at 2030 (SCP).

For the purpose of the definition of the measures on public lighting systems, the action must be related also to what is specified in the Municipal Public Lighting Plan adopted (DG 00517/2009), which shows the lighting classification of the place. This efficiency plan meets the regional and ministerial legislative framework. The traffic laws are regulated at national level.

Incentives:

There are several energy savings programs at national level: the energy efficiency titles ("white certificates") are the main supporting measure in case of public lighting measures.

For metropolitan areas, other financing programs are in place for infrastructures and suburbs (PON Metro, "bandi periferie",…)

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Human factor (success factors, opposed sentiments, …)

The interventions reducing lighting power have to be shared and agreed with local stakeholders and authorities regrading cultural heritage, monuments and landscape. The additional services need is a driver for the infrastructure optimisation while the investment costs are the main obstacles (supported by the energy savings but only in case of old lighting systems).

Competitors

ESCO market related to LED implementation

First findings and scale up analysis

Impacts

The action will reduce the energy consumption of the public lighting network (and the GHG emissions): the actual consumption in the district is about 4,5 GWh/y, while the foreseen consumption is of 2,6 GWh/y (savings > 40%) i.e. 650 CO_2t/y saved.

Increased safeness in the district is another important impact. A huge amount of data could be made available to the municipal control room to increase and manage the safety and vigilance of the area

In an urban context like Florence the optimized impact of the services infrastructures plays an important role. The impact of other infrastructures (WiFi network, video surveillance, traffic & access control, ...) has been minimized while their coverage has been widened

There is also an impact regarding capacity building and jobs, because SILFI, the third-party municipal company acting as an ESCO, will increase its skills and market chances.

Lessons learnt

- The city and its territory: the national legal framework and the local peculiar situation (cultural heritage) have deeply influenced the realisation schedule; these different boundary conditions ought to be taken into account in the replication plans
- Regarding sensors and video cameras maintenance is a crucial issue. The Sensors deployed have to be maintained providing remote service as much as possible. Each Sensor depending in the complexity shall be reachable both in VPN or directly using a public IP address. This will allow remote diagnosis and intervention. In case of very simple sensors it is mandatory to foresee a remote "OFF command" and "ON command" able to cut off power in such a way that the sensor can be shut down and restarted.

Optimal scale for next implementations

The implementation will be extended at city scale but also at metropolitan level in the near future.

Further developments needed

Those services are evolving fast and their integration has to develop following technological improvements.

Expected impacts

The impacts described at district level will be extended to the whole urban area

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Solution 5: Citizens Participation Platform

Main partners involved: Eurohelp, Fomento San Sebastián, ADS (San Sebastian Municipality)

Short description of the action

This action includes the analysis, design and creation of a citizen participation platform that will allow improving the management of the participation processes.
The platform will include an internal private web to manage the overall project, open a project, include participants, upload information, define target citizens, define schedule and participation format. The platform will also include an open section that citizens can visualize, and where they can get information about a project and participate actively. The project responsible will define whether all the participation moments are open to all the citizens or are restricted to a specific group. All the results of participation can be also managed through the web, allowing decision taking for municipal departments in charge of the process.

Value proposition

The aim of this project is

- fostering citizen participation through new technologies, avoiding face-to-face surveys and voting processes.
- fostering data publication and participation of citizens in decision taking
- develop an efficient information management, data sharing and decision-making process.

Technology

The Participation Platform is based in two web architectures. On the one hand, there is an internal management website. In this site, the participation technicians can manage all the participation processes, phases, actions, results, etc. This website is a Java based website, developed using these technologies:

- Java EE stack + Spring framework.
- DB2
- HTML5, CSS3, JavaScript, JQuery, Bootstrap.

This management site is deployed in a intranet context, so as only the staff from Participation department can access it.

On the other hand, there is a public web site where citizens, companies and associations can access to participate into the participation processes. Participation processes published from the

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

management site are shown in this public site. Citizens, companies, associations, etc. can access to all the information of the participation process and can see which actions are open to participation. Depending on the kind of participation configured on the management site (only for citizens, certificate required, etc.) participation requirements change. This website has been published into municipal website at https://www.donostia.eus/ataria/es/web/partaidetza/home, integrated with the rest of municipal information.

This website has been developed using these next technologies:

- Java EE stack + Spring framework.
- Liferay Portal + Spring MVC Portlet.
- HTML5, CSS3, JavaScript.
- Responsive Web Design.
- SurveyJS

Main impacts:

Direct impacts:

The direct impacts of the participatory platform for citizens are the following:

- Easy and better management of these participation processes.
- Greater involvement of all the citizenship in the city government
- Greater transparency in the decision-making processes
- Public involvement brings more information to the decision, including scientific or technical knowledge and knowledge about the context.
- More views gathered in the process of making a decision means a higher likelihood that the final product will meet the most needs and address the most concerns possible.

Indirect impacts

- better outcomes for all stakeholders, as the project has a greater public support
- lower project costs
- Political stability.

Enablers and obstacles

Competitors

The main competitor is the open source project Consul: https://github.com/consul/consul this software is used in Decide Madrid citizen participation platform: https://decide.madrid.es/
However, it has some limitations as pointed by local Administrations from the Basque Country. Mainly from the point that citizen participation is left too much open, in the sense that all proposals are

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

originated from the citizenship. Getting an effect contrary to the expected: many more proposals are created but few manage to get enough support, as they are diluted between the incessant number of new complaints and suggestions. The approach demanded by the Basque Administrations was to maintain this initiative from the citizenship, but also to facilitate the discussion of proposals made public by the Administration itself, achieving a greater impact and participation in the proposals and debates launched and, thereby, engaging more actively and effectively to the citizens.

Legal framework & incentives

- "Norma Técnica de Interoperabilidad de Reutilización de recursos de la información" (BOE-A-2013-2380). It defines the URIs and compulsory metadata (DCAT based schema) for resources published by official institutions.
- "Ciudades Inteligentes. Datos Abiertos (Open Data)." (UNE 178301:2015). It defines the technical requirements for the Open data provided by an intelligent city. It provides a scale to assess the compliancy level of a given city.

Human factor (success factors, opposed sentiments,…)

- Financial support is needed for the co-ordination of citizen engagement programmes.
- Ensuring a clear and user-friendly web structure of the participation platform
- Point out and mapping the issues citizens care about across the city;
- Coordinate the platform with variety of stakeholders.

The obstacle is represented by lack of citizens sensing programme, expertise or interest. Citizen participation through new channels may be difficult to understand and apply for the municipality and difficult to use for some citizens.

First findings and scale up analysis

Lessons learnt:

- Need to activate new channels to connect with citizenship, foster and facilitate their participation in specific decision-making processes.
- It is important to use on-line citizen engagement in decision making process which directly impacts on citizens' life
- The more specific the subject of participation is, the more feedback is obtained.
- The more citizens can identify themselves with the engagement topic, the higher involvement rate will be achieved.

Optimal scale for next implementations

Any scale is possible

Expected impacts

Increased efficiency in the management of issues of public interest.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Solution 6: Smart City Platform and control room

Main partners involved: City of Florence, UNIFI – DISIT lab, Thales; e-distribuzione, Mathema, Telecom and SPES are also involved.

Short description of the action

Replicate is providing the city of Florence with an ICT platform on which its Smart City Control Room is built upon.

In the development of a Smart City there is a great emphasis to the set-up of the so-called Smart City Control Room, SCCR. A SCCR is an area in which all the data are collected, aggregated and where high-level data/results are summarized and made accessible for the decision makers and shared to the city operators. In large metropolitan cities, the SCCR includes large panels/monitors (even covering large walls) in which the status of the city is reported in real-time presenting the view of the city with some synthesis, predictions, alert of data regarding: mobility, energy, social activities, environment, weather, public transportation, people flow, health, water, security, ICT, governmental, first aid, civil protection, police (118/112/911), fire brigade, hospital triage, and thus almost all the city resources expressed via Key Performance Indicators.

The main functions of the Replicate platform are:

- Collecting data about the territory and the related services from available sources (with specific agreements)
- Integrating new infrastructures in the database (IoT, e-mobility, …)
- Storing and processing the data collected
- Analysing some data set (benchmarking, warning alerts, trends,…)
- Visualising the data in tailored dashboards for the different city users
- Enhancing data transferability (thematic platforms, open sets, APP developers,…)

A specific focus has been made about the security of the platform thanks to the expertise of the consortium partners. Two Apps have been developed linked to platform data

Value proposition

The main target of a city platform is to support the city management and the citizens' quality of life collecting, processing and providing data. The Florence specific solution has been realized to allow integrating a large number of heterogenous data, static and real time, obtained in Push and Pull, provided via multiple protocols and different format and standards, from files, streams and IOT protocols as well. The market solutions are not adequate to cope with the above described complexity.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

The security issue has been targeted as well as the privacy to optimise the customization of the Florence ICT platform technology.

Technology

The solution in use:

The REPLICATE Florence Smart City ICT pilot is a complex eco-system of data platforms, IoT, smart mobility, smart energy sub-systems, and web and mobile applications. The overall architecture of the City platform is sketched in the following figure.

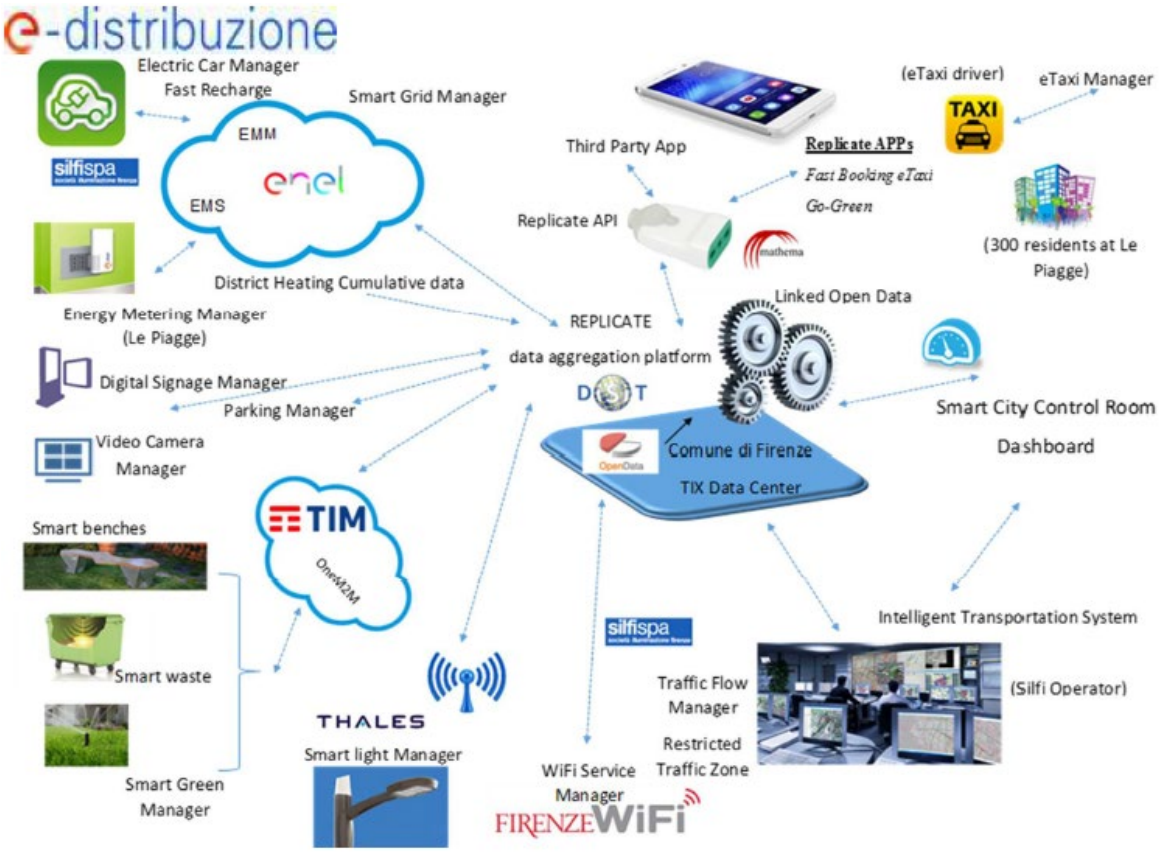


Figure 9.18 – Florence ICT platform architecture

On the left side of the picture above, the different city sub-systems are sketched: the e-charging city infrastructure is connected to the smart city platform via the e-Distribuzione Electric Mobility Management (EMM) platform. The smart info meters are connected through the e-Distribuzione Energy Management System (EMS) platform. The Digital signage networks and Video Surveillance are connected through dedicated interfaces. IoT sub-systems include the Smart bench in Museo Novecento, plus other 4 smart benches to be implemented during 2019, the Smart Waste trial and the Smart Irrigation platform in two parks in Florence. All the three IoT sub-systems connect to the Data platform via the TIM OneM2M platform. Smart lighting and the city public WiFi are linked with

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

the Data Platform via dedicated data integration. All these data sources, plus the city Open datastore, are the input to the Florence REPLICATE Smart City Platform, developed by Unifi and representing the first big data and advanced analytics platform for the city.

The other most relevant component of the Smart City platform is the Traffic Supervisor, which is both a data source for the Florence data platform and an additional user interface for the Smart City Control Room users.

All these data are offered to the control room end user and also are a feed for the two REPLICATE mobile apps, namely FastBooking and GoalGreen.

The Smart City Control Room is a new paradigm of operations control centre where routine operation of the city is controlled, monitored, and key performance indicators are reported to the top management.

The two main target users/actors of the Smart City Control Room are:

1) Top management/Policy Makers (Mayor, General Director, Head of Departments)

2) Operators of the Smart City Control Room (belonging to the Municipality, to public utilities, etc.)

The first type of users will use the SCCRoom data from their Main Quarters or in mobility, most likely on mobile devices, and with very high-level of abstraction regarding the city operation levels. Actually, the Mayor himself is already using the SCCRoom dashboard to monitor the city daily operations.

Head of departments will be able to access to specific dashboards dealing with thematic areas (e.g., the Head of Environment dept will access the section regarding environmental data). At the same time, he/she will be able to access dashboards regarding other areas, thus making it possible to correlate different and heterogeneous events and to better understand and approach critical issues.

The second type of users will use desktop-version of the SCCRoom, either within a common control room where all the stakeholders have an on-site representative, or from the respective specific operation centres.

The REPLICATE dashboard and platform within the SCCRoom can be sketched as follows, in relation to the other internal management systems of the different utilities and operators involved in the Control Room:

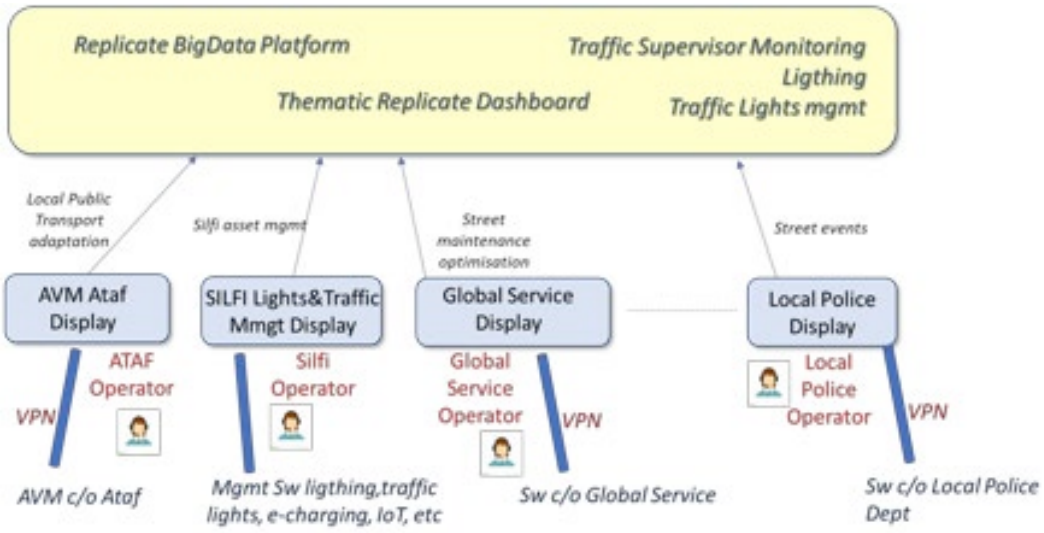


Figure 9.19 – Information Systems & Information delivery of the Smart City Control Room in Florence.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

The Florence Smart City Control Room will be deployed also in facilities managed by the Municipality of Florence.
The users of the SCC Room will be mainly employees of Florence Municipality and Florence public utilities, located in a shared equipped control-centre room with multiple displays as sketched in the figure above.

The general architecture of the data aggregator is reported in the following figure:

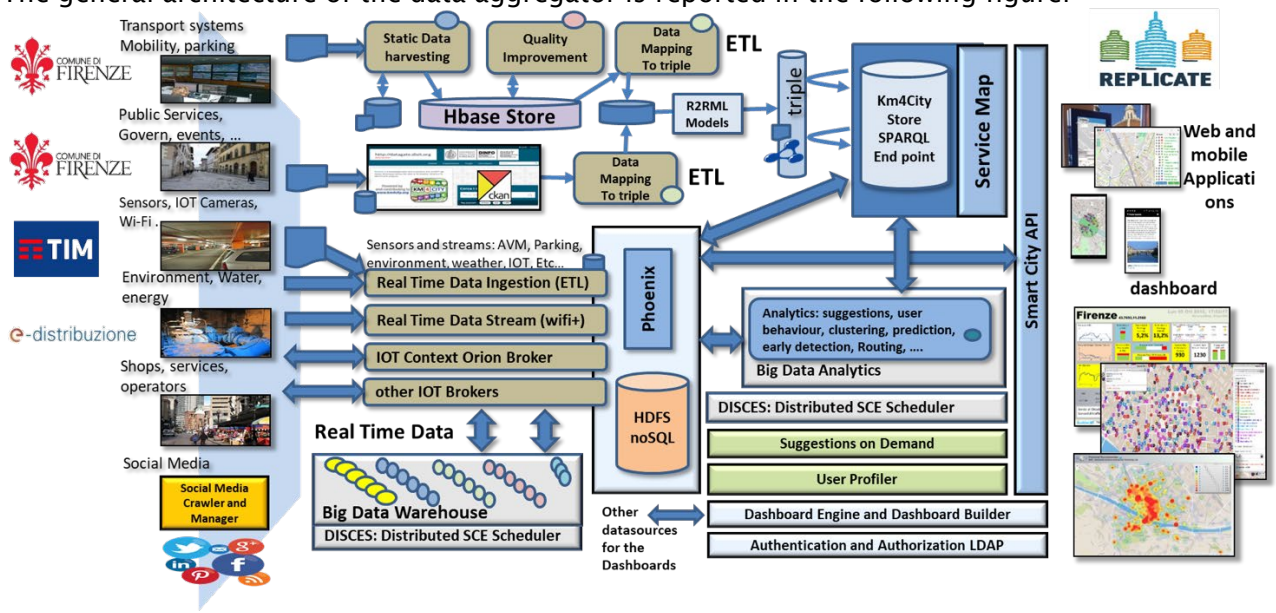


Figure 9.20 – Florence ICT data aggregator architecture based on km4city solution by UNIFI

The adopted technologies have been selected to avoid vendor lock in, and are very effective with respect to the state of the art. The ICT Platform developed, listed on Fi-Ware official web site, includes all the following Open Source Components:

- *Km4City Ingestion Processes based on ETL and DISCES tool.* Data acquisition processes via ETL processes and scheduling based on DISCES of DISIT lab. These components have been chosen since they are at the state of the art, in the sense that in most cities the data gathering for static and real time data is performed via ETL and the processes are scheduled. In addition, the DISCES can also put in execution and manage any kind of data analytics, for example, prediction on parking, computation of total traffic flow, etc.
- *Km4City ServiceMap:* Semantic Data Aggregation on the basis of Km4City Ontology and model and Smart City API for apps and dashboards. This component is highly innovative since it allows to perform a semantic mapping of any data so as to arrive at creating a knowledge base of the city entities on which one can: (i) perform semantic queries in SPRQL, (ii) access via Smart City API, (iii) access via MicroServices for IOT Applications.

In detail ServiceMap allows to:

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

- perform full text queries on street names, service name, description, areas, categories, etc.;
- perform queries to get geo-located services closer to a given point (proximity query), with and without filtering;
- work on simple and complex geographical areas: region, districts, metropolitan area, municipality, restricted traffic zone, etc., and allows to query for collecting services with and without filtering and/or clustering;
- show areas and surfaces (e.g., RTZ, parching area, green, districts), lines and polylines for paths (e.g., bus lines, cycle lines, bus lines, train lines), events information, bus lines courses and delays with respect to single bus-stops, sensors data, etc.
- monitor real time data: events, bus lines, sensors, traffic flows etc.
- report from real time data collected. For example the data results on bus line reports about deadlines, parking status, sensors, traffic flows, etc.

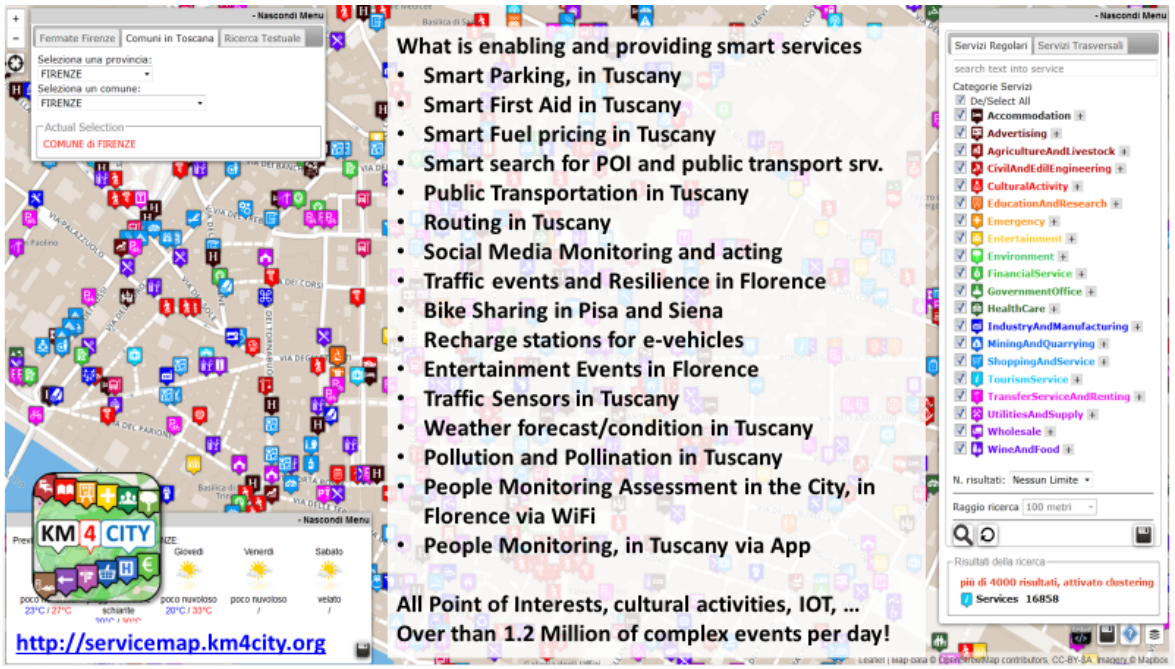


Figure 9.21 – the service map

- *IOT Orion Broker.* This component has been reused and configured to work with IOT data of Comune di Firenze, and for interfacing with the data aggregator above. This component is not innovative, a large number of other IOT Brokers are available, and can be used as well into the provided platform that is IOT Broker agnostic. It has been chosen since it is compatible with of the FiWare tools.
- *IOT Applications* for data drive processing. It is based on Node-RED/NodeJS, and it is integrated with Snap4City MicroServices (exploiting Km4City Smart City API, platform control, notifications, IOT devices and Brokers of several kinds, and Dashboard of DISIT lab). It has been chosen since NodeJS is almost a standard in IOT and it provides a visual interface for IOT App programming. All tools are also available on JS Foundation Portal.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

- *Dashboard Builder:* a component developed by DISIT Lab with REPLICATE in PHP, Java. It includes a large number of graphical widgets for showing smart city data: KPI, POI, maps, trends, gauge, gears, semaphores, triage, and micro applications, and also external services can be integrated as well. It has been developed by DISIT Lab instead of reusing a third-party open source tool since those that have been tested where not satisfactory as reported in previous reports.

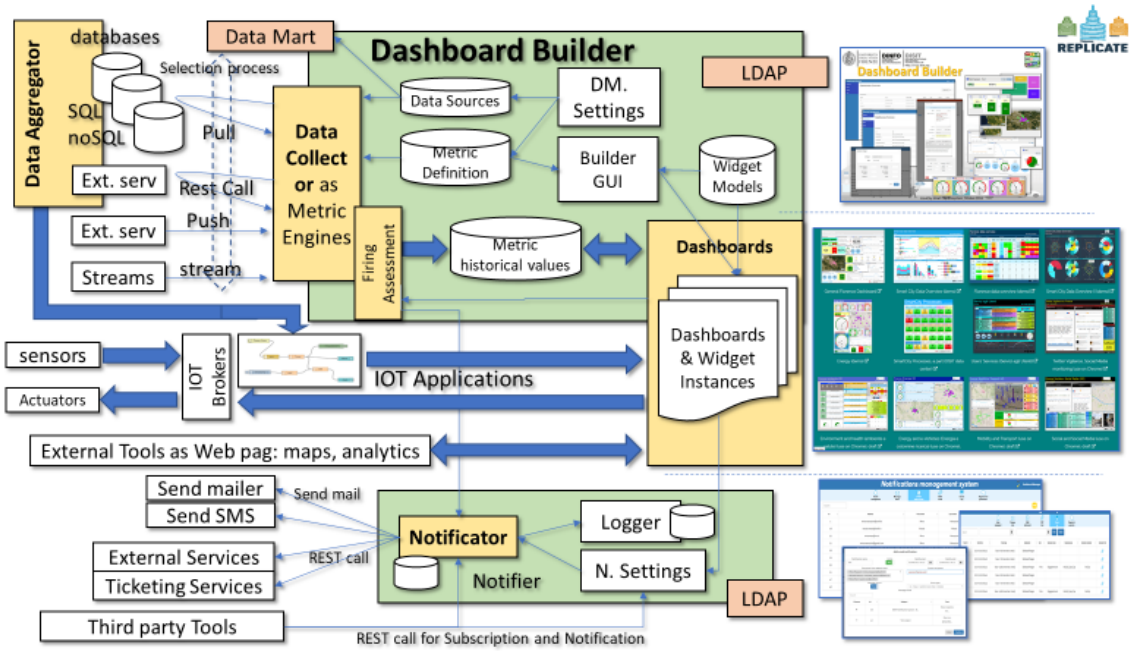


Figure 9.22 – the dashboard builder

- *Twitter Vigilance*: is a technology and tool proprietary of DISIT Lab, thus is not released in Open Source. A full service to use the tool has been provided to the Comune di Firenze to monitor Twitter according to multiple control channels and keywords. The data collected can be accesses and the graphs can be directly shown into the Dashboards.

Figure 9.23 – twitter vigilance

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

The resulting dashboards of the new generation are similar to the following:

Figure 9.24 – example of tailored dashboard for the Mayor

Innovation solution

The REPLICATE platform and Smart City Control Room, above being a very innovative governance approach, is composed of a set of very innovative sub-systems and tools in different areas.
For instance, the Km4City platform has been recognised as an innovative solution across multiple contexts in Europe, such as the Select4Cities challenge: this UNIFI system for data aggregation and dashboarding is strongly innovative with respect to the state-of-the-art solutions as it is more scalable, robust and complete.

Main impacts of the measure (economical, environmental, social)

The main impact of the SCCR in the present implementation are related to:

- More awareness for the decision makers about the city evolution and multiple problems that may occur. In the cases of events, they may exploit a virtual chat room for discussion attached to the dashboard.
- More effective response to the events. Increment of reactivity to problems.
- Possibility to inform the city users according to a number of facts

Direct impacts:

ICT technologies present a wide range of indirect impacts being a tool for the main city departments for a responsive control on the territory.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

The REPLICATE project allowed the City to go beyond the Open Data phase, to experience a real Big Data and smart city initiative, and this was done not just from a technical perspective, but also was accompanied by a cultural new approach from top decision makers (the Mayor and the City Manager themselves) to the technicians working in the field to manage the daily public services, to the citizens that are being physically brought with schools to touch the innovation systems and see live how the public services of the city can be managed and monitored in new ways thanks to the Control Room dashboards collecting data from different subsystems.
It is a shift of approach to the management of services, that also brought as a positive outcome a stricter cooperation among different technical departments of the Municipality that previously were working more as vertical silos. Synergies among Environment, Mobility, IT and Technical departments have considerably increased during the project lifetime.

Indirect impacts:

The indirect impacts can be environmental due to the possible consumption savings in the different sectors monitored (buildings, mobility and services like watering and waste collection).
The main social impact is the improvement of citizens' quality of life (less time for travelling, better air quality, lower fees for services or improved services, security,…) but there is also the encouragement of digital entrepreneurship and the enhancement of citizens engagement.
The proposed solution for data aggregation and dashboarding can be used to inform the citizens about eventual problems in city, for example via Dashboard, via Smart City API and the corresponding mobile Apps.
Financial impacts are inked to the improvement of city management even during critical events.

Market analysis: enablers and obstacles

Legal framework:

Within the framework of the European Digital Agenda, Italy has developed its own national strategy, identifying priorities and methods of intervention, as well as actions to be carried out and measured on the basis of specific indicators
The European Parliament and Council in the Directive 2003/98/EC approved on the 17/11/2003, enhanced the re-use of public sector information. The EU General Data Protection Regulation (GDPR), updating the Data Protection Directive 95/46/EC, has been adopted in 2016 to harmonise data privacy laws across Europe; it entered in force finally all over Europe on the 25th of May 2018 (https://ec.europa.eu/commission/priorities/justice-and-fundamental-rights/data-protection/2018-reform-eu-data-protection-rules_en)
Among the international standards about ICT, it must be reported the DIN SPEC 91357 - Reference Architecture Model "Open Urban Platform" (OUP).
With respect to local initiatives for digital agenda and smart city, the city of Florence has been a front-runner in the ICT sector and the ICT "renaissance" of the city has been stated in its "Digital Manifesto": a reference point containing the digital values considered fundamental for the city for the municipal administration and subsequently to all the subjects that provide public and private services in the city. On the basis of the Manifesto a three-year 2016-2018 Digital Florence action plan has been

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

implemented, involving the Municipality, the local Chamber of Commerce, the Tuscany Region and all the public utilities in the city. Main objective of this action plan has been to promote digital assets sharing among the different public service providers (WiFi, digital ID, digital payments, one-stop shop, data) and to maximize the dissemination of the available city digital public services to all the different city users. The action plan is going to be renewed also for 2019-2020 years.

incentives:

Above the H2020 SCC and ICT framework, there are several EU and national programs supporting the development of city platforms (UIA, PON METRO, …). In case of the single services/data sources, the chances of finding a supporting program are generally high depend on the specific theme (public lighting, E-mobility infrastructure, district heating systems, IoT solutions, mobility, …)

human factor (success factors, opposed sentiments ,…):

It is necessary to provide tailored dashboards for different user roles and a specific training. The dashboards developed with the solution realized are very user friendly and graphically appreciated. A relevant amount of work has been done in the project to improve some aspects and the results is very attractive and easy to use.

Competitors:

Ultimately, no single platform will be able to offer all features for all verticals in a smart city environment characterized by a "platform of platforms" approach, with open, interoperable platforms interacting with and complementing each other in a "system of systems" constellation and open ecosystem ('next-generation smart city IoT platforms' ABI Research, March 2018)

There are many competitors among the industries such as the solutions of IBM, HP, CISCO, Siemens,... but they are almost focussed on creating a specific solution for very large cities and propose largely proprietary solutions. On the contrary, the solution produced is totally open source, and thus can be installed on premise at zero licensing costs and may be adopted on cloud as a service as well. Among the open source platforms for smart city: Indra, Fiwoo, Bosonit, etc. We think that our solution is the most powerful for realizing a control room since it allows to: (i) gather any kind of data type via ingestion processes; (ii) render on graphics a large set of high level types (KPI, POI, external services, sensors, actuators, selectors, tvcam, weather forecast, triage, DSS, heatmaps, microapplications, etc.); (iii) fully integrate multiple IOT protocols and networks; (iv) support GDPR in managing personal data; (v) support private chat rooms for each dashboard; (vi) create full interactive applications with drill down on time, space and relationships of city entities and their data.

First findings and scale up analysis

Lessons learnt

- SCCR:

Typically, in medium sized cities, the daily management of city resources is performed by a set of separate city operators and in most cases also delegated to in-house companies, such as: energy operator, water providers, several telecom operators, several ICT infrastructures for the different level of govern to provide different services, civil protection, etc. This means that all of these separate city

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

operators are autonomously managing their control rooms, with access at their own data to take their own and limited decisions.

The presence of a set of independent control rooms may be a positive issue to be reactive and solve microproblems autonomously but, in presence of relevant disasters the distributed solution is not efficient and effective as it should do for the lack of concertation and synchronization of knowledge and actions. In addition, in some cases, cascade effect may be provoked. Since most of the critical events in the city impact on multiple infrastructures and may provoke cascade effects, a stable SCCR in a single place can activate cross information among the several control rooms of the city operators, saving communication time, reducing misunderstanding among operators and exploiting synergies in the interventions.

- REPRESENTATIONS AND DASHBOARDS:

The ingestion, aggregation and data analytics processes are very complex to be managed since the information is heterogeneous (different format, providers, protocols, etc.) and the total amount of data is a Big Data problem, moreover, the final indicators, provisions and suggestions calculated by these complex processes must be easily understood by the observers of the panels. It is a problem of data representation which also must consider the competence of the final users: citizens /observers/operators/experts/decision makers/etc. In most cases, the final users have to be trained to understand the data and graphics representations. They must become confident on what they see to understand in deep all the single details represented on the screen, because they are not going to have time to learn when a critical event happens.

- PLATFORM AND DATA SOLUTIONS:

A set of solutions, both commercial and open-source, have been analysed to identify a functional platform to be adopted. Most of the solutions which are present at the state of the art derive from business intelligence solutions (e.g., SpagoBI (http://www.spagobi.org/), Tableau (https://www.tableau.com), OpenDataSoft (https://www.opendatasoft.com), etc.), in which the tools provide some data mart (data virtualization) tool to access data sources and thus have powerful tools in this sense. On the contrary, they provide limited capabilities and tools on rendering and dashboard for control rooms that must stay H24/7, rendering specific kind of structured data. For these reasons, several specific custom solutions have been proposed by many cities such as: London (https://data.london.gov.uk/), Amsterdam (http://citydashboard.waag.org/), Dublin, etc. On the bases of the analysis made, regarding the solutions available on the market, none of them satisfied all the requested functionalities and functional aspects, above described, and this is the reason why we decided to start the development of our solution, ([Bellini et al., 2018]).

The Municipality of Florence already has expertise in managing large data integration platforms, because in 2003 it started a massive data integration and quality project which produced in 2006 a data platform which every night integrates more than 60 information systems of the Municipality with complex ETL, data quality and string-matching algorithms. However, the complexity of the REPLICATE data integration process was due to the fact that most of the data sources involve external process owners of the Municipality.\Therefore, the REPLICATE project is helping the city to build its first real data lake with nonpersonal data belonging to several different actors, and with a wide set of different

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

features and formats.\Also the data licensing and agreement aspects were particularly taken into account during the Project.

Optimal scale for next implementations

In small cities, with about 100.000 inhabitants the number of relevant data sources to be integrated by the data aggregator and represented in Dashboard can be in order of 10-15 while in larger cities they can rapidly grow for the presence of multiple operators for each utility.

The solution for SCCR is scalable and robust. In addition, it can be installed on premise or offered as SaaS approach, or better as SCaaS, Smart City as a Service. This approach is enabling also the data sharing among the several cities.

The solution is economically feasible and may pass to provide support for small and large, and very large cities since the solution is modular, flexible, and scalable. In addition, in Snap4City, in most cases the activities in configuring or creating the flying button that is demanded to spin-off.

The work performed in Florence towards a Smart City Control Room has been valued also by neighbouring cities and communities, which are going to replicate or scale-up our approach.

For example, the Tuscany Region with Regional Delibera n. 383 of 18th April 2017 adopted a Partnership Protocol for the development of Smart Cities among the main cities in Tuscany.

The work done with public utilities – above described – can be easily replicated in other communities, or also scaled-up with the involvement of upper-level governments (such as Regional Administrations).

Further developments needed

Smart City Control Rooms are focused on Dashboards. The dashboard production is a continuous working for improving city monitoring, adding more data, focusing on critical issues that may have seasonal aspects, follow special events, and/or works for city improvement and maintenance. Complexity is due to the needs of data aggregation and to the identification of modalities to present data, their prediction, early warning, etc., and corresponding notifications.

Expected impacts

The Triennial Plan for IT in Public Administration foresees the DAF, a national platform collecting data from different cities.

The Municipality of Florence hosted a national hackathon in Oct2017 to connect the Florence Smart City platform on which REPLICATE is based to this national framework. Two start-ups in the final ranking developed connectors from REPLICATE to DAF (Data & Analytics Framework), representing an interesting first effort for the connection of a smart city platform to a national data platform for analytics.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Solution 7: ICT Platform

Main partners involved: Bristol City Council supported by Bristol is Open, University of Bristol, Zeetta

Short description of the action

Historically Bristol's Smart City approach has been to enable the local digital community the space to try out new things: Bristol has a large and dynamic digital start-up scene. The literature would define this as a "Beta City" approach.

More recently this approach has matured and specific experimental testbeds (such as Bristol is Open (BiO) and the REPLICATE project) have been developed, and this has shifted the city's position slightly towards the use of civic platforms that can accelerate the adoption of new ideas at scale, whilst trying to retain the city's historical dynamism.

In Bristol, this has resulted in the creation of a core set of platforms, integrating with existing smart city infrastructure and a series of use cases for joined up data management across the various elements of the Programme.

The Bristol Smart City Platform (SCP) enables access to a variety of data sources, relating (amongst other things) to energy consumption in our smart homes, status monitoring of electric vehicles (EV) charging points, tracking of electric vehicles and electric bike journeys etc. It allows a variety of stakeholders, such as the Council, SMEs or citizen interest groups, to develop solutions generating data and offers a way to store and integrate it meaningfully with other data streams on the platform. The overall architecture allows the development of solutions that capitalise on data access in order to build insights into patterns of energy and mobility services use and where appropriate, react to ensure smooth city operations and service provision for its citizens.

Value proposition

The Platform partners have developed systems and software from scratch and combined these with the adoption of a range of existing open source components. Combining technologies from local innovation and research, Bristol has now created a platform that is being utilised by 150 Smart platform has been developed to provide high Quality of Service (QoS) to the platform users, as well as to the platform operator.
The platform was built as an ecosystem rather than a stand-alone platform and will be more adaptable to add functionality as services are developed and needs are identified.
Homes and includes e-bikes, Electric-Vehicles, charging points and a shared taxi. Gathering data from all these sources to the cloud and using novel algorithms for processing the data, a cloud IoT

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

There are two dimensions to the value of the REPLICATE platform:

- City operations: providing mechanisms to understand, predict, or deliver municipal services; and
- New use case generation: the ability of the platform to satisfy cross-cutting use cases.

Both of these dimensions drive better citizen involvement and defines the ability for the platform to engage and inspire citizens to greater digital participation in the life of their city.

This has been tested in BiOs closed loop environment to ensure critical services are not affected while in development and testing; and a council owned EcoHome has been utilised as a test house.

With Energy Providers and Network Operators having to balance Energy Supply and Demand at all times, the flexibility of Energy Demand has become a valuable resource with financial and ecologic incentives. Our objective within REPLICATE is to demonstrate how using our SCP, along with an energy demand management system (EDMS), can orchestrate the demand flexibility of small consumers into larger, more powerful optimisations.

Technology

The solution in use:

At the heart of the platform, a layer of FIWARE middleware enables registration and collation of smart devices with associated periodic or event driven data. Those smart devices could be, for instance, energy usage monitors, energy controllers, air quality sensors, mobility sensors or lighting. These are collectively grouped as of Internet of Things (IoT) devices. This layer is responsible for contextualising the received data (e.g. adding metadata descriptions, linking to existing records of related information for a known entity etc.) and storing it appropriately in efficient back-end databases. We currently use MongoDB for this purpose, but any database technology could be used to similar effect.
The overall network architecture ensures that data is transferred to the platform through secure connections. The FIWARE layer of the SCP can also receive and respond to requests for data related to devices from which analysis and decision support systems could act upon the provided information, such as our EDMS. Finally, using the FiWare platform technology for this Project, has proved ideal as it is already open and contains useful API features that enable us to link to a wide variety of commercial, open source and bespoke developed visualisation and application development platforms. The creation of relevant dashboards for a variety of viewpoints is feasible and further work on this will commence in the near future.
Bristol city has tended to work with a model of the platform as an overall ecosystem of co-operating services as shown in the following diagram.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

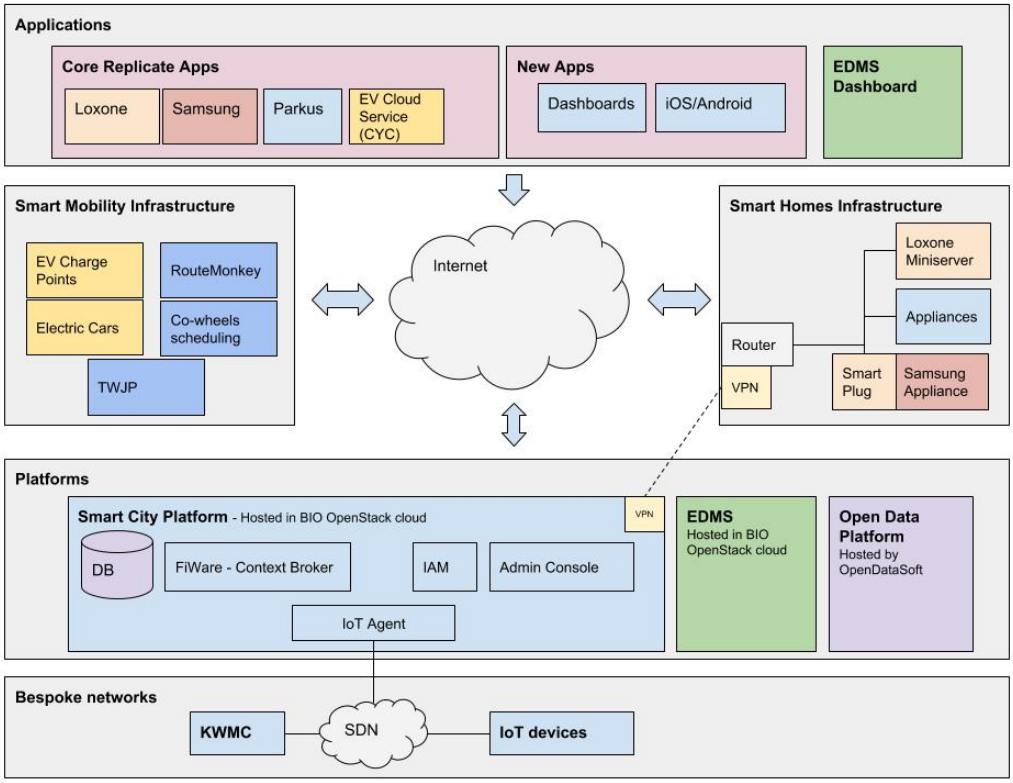


Figure 9.25: the platform model

For the purposes of the Replicate project the platform is defined as those elements that were adopted during the programme to support the Replicate mission. However, because what was built was an ecosystem rather than a monolithic platform, we should envisage it as more of a set of concentric circles.

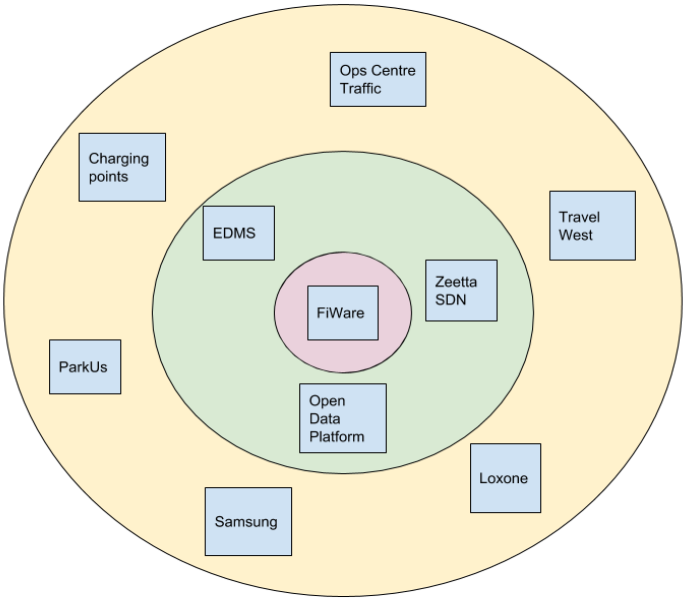


Figure 9.26: the services ecosystem

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

The further out an element is, the more subject it is to change and adaptation – and the more incidental to the Replicate platform it becomes.
For the purposes of platform impact measurement, we propose to only focus on metrics relevant to the inner two circles, comprising the core FiWare broker, the Energy Demand Management System (EDMS) and the Zeetta Software Defined Network (SDM). Even at such a core infrastructure layer, however, our focus must be on how the platform enables our wider goals and not on simply measuring traffic, code or processor time used; our platform must be judged against its purpose.

Innovation

The core idea of the Bristol SCP was to create novel smart city applications and develop real use cases of cutting-edge technologies. The main technologies used in REPLICATE are Internet of Things, Software Define Networking and Cloud computing. The Bristol Smart City Platform is a combination of all of these technologies and the ultimate goal is to deliver a Cloud platform that utilises a novel architecture. It is designed to facilitate the sharing of data from heterogeneous services across the urban landscape – regardless of who might provide them. To accomplish these objectives, the Project had to satisfy a number of prerequisites, and eventually developed and delivered a platform that can collect, optimize and provide data in real time.
Modern computing architecture has been utilised in the core solution. REPLICATE is built on virtual machines, designed to be distributed across a private dedicated OpenStack cloud. Running the city's own platform means municipality can explore the option for a more cost effective and agile system to respond to change rather than relying on commercially available platforms.
The platform itself has brought together a leading edge IoT platform (FiWare) and some unique code around the Software Defined Networks, which has enabled multiple inputs and outputs for data on the project. The value of this data will be assessed during the monitoring period.
The SCP has the ability to assist with the remote monitoring of energy consumption, an idea that has been explored recently within utility companies. As more homes across the UK are now installing smart meters, this remote monitoring has removed the need for home visits by a human meter reader. The difference between smart meters and the Loxone device however is that we can drill down into the data to attribute it to individual devices rather than the 'whole property' via the smart meter alone.
The citizen sensing program has opened up a whole new world of opportunity and innovation. Knowle West Media Centre, university partners and local community engagement organisations have been able to tease out the real needs and fears of the community around sensing and Big Data. The citizens want to control and own the design and decisions around what is sensed and by whom. The consultancy and SME opportunities are here to exploit.
The use of sensor packs in the citizen sensing program also opens up opportunities for using the SCP as a filter or funnel for sensor data. Mixing community data with data from central sources to help expand our knowledge and collaborate our results. This could mean the Council could source input from its communities and not have to use expensive studies form consultancies

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Main impacts

Direct impacts

The main benefit to municipal services from the REPLICATE platform is around the value of the research conducted as part of the Programme. The platform generates large quantities of data about energy use, travel habits, and the potential for creative ways for communities to work together to maximise their energy assets. This information can in turn influence policy, future projects, budget priorities, consultations, urban planning and service delivery.

The platform allows us first to combine the data from smart energy devices from multiple domains (currently homes and charging points). Upon establishing a baseline, monitoring is then possible to develop energy community programs (e.g. by retrofitting micro generation capabilities) with both monitoring and control logic, where self-learning management algorithms can cope with uncertainty in demand predictions.

Other application areas include monitoring of EV charging point operations by the Council's mobility teams. EV Charging Points implement the Open Charge Point Protocol 1.5 or 1.6, a method that among others, sends messages to Charge Your Car's (CYC) back office when status changes

Bristol City Council (BCC) uses a Feature Manipulation Engine (FME), a data integration and workflow service, to get the status of all charge points in the network every 2 minutes. Using FME, the data from REPLICATE charging points is filtered and the related data uploaded to SCP using FIWARE's bulk upload functionality on a service and devices that have already been provisioned (i.e. have been verified and enabled to access the network). BCC has also piloted the latest Open Charge Point Protocol 2.0 format for this. After data has been imported into the SCP, it is then possible for NEC to get this data for EDMS and Route Monkey for performing route optimisation via their app. Separately, BCC manually downloads monthly energy usage of REPLICATE charge points and sends this to NEC and Route Monkey in CSV format, to enable development of further analytics.

Indirect impacts

There is great potential for bringing data together (such as air quality) from a variety of IoT devices (some hand-held citizen devices, others city council devices), to not only assess the issues in local areas, but also start the creation of a joint narratives, that can influence change both from the bottom up and the top down.

Apps like Samsung SmartThings™ allow home owners to control their washing machine or tumble drier remotely. This removes the need to remain at home during laundry cycles. It is now easier to place detergent and laundry in the washing machine, or wet clothes in the drier and go out and control the device to be switched on remotely, from any location via a smart phone or tablet.

There is also the social value of comparing and contrasting technology, there is a certain 'wow factor' when explaining to your peers you are participating in a smart cities experimental initiative and contributing to a European wide project. Also, there is an impressive design quality to the devices, allowing home owners to showcase the latest technology at home.

It is essential that any SCP can share data, preferably through an open data platform. The Bristol SCP aims to expose data to a variety of different groups at different levels of granularity to a variety of

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

platforms. An example of this is the link the BCC open data platform to share data more widely, the shared data for the Travel West platform or for the EDMS

Market analysis: enablers and obstacles

legal framework

The legal framework influencing this measure

The General Data Protection Regulations (GDPR) were implemented on 23 May 2018 in the UK by the Data Protection Act 2018 (As Amended). Bristol City Council is defined as a 'Public Body' as defined by Section 7 of the Act. This also gave special new considerations to the collection, processing and retention of personal data. REPLICATE smart energy and smart mobility data sets are deliberately designed to be collected using anonymous and unique reference numbers (URNs) so as not to identify individual users. The data is collected to analyse energy usage trends, identify opportunities to offer customers cheaper tariffs, monitor uptake of novel technology such as Smart appliances or EVs and ultimately lower Bristol's carbon emissions.

All data is transmitted between IOT sensors and the platform via secure VPN tunnels. The backend systems are protected by a firewall and server environment has anti-virus software.

Bristol City Council is the owner of the data produced, GDPR compliant data sharing agreements are in place with the various partners to allow dissemination of information.

Incentives

Citizen use cases:

- Smart heating and congestion
- Saving money on electricity tariffs by weather forecasts and nudge
- Remotely solar powering home appliances
- Timing home appliances for best performance

Community use cases

- Calculating the ROI of community solar projects
- Lobbying for better transport links
- Identifying gaps and opportunities for community assets

Municipal use cases

- Change planning policy based on demand/supply for community energy
- Change of use of buildings/land/areas to smooth out congestion
- Adaptive street lighting
- Identify leading indicators of health issues and nudge behaviour

Human factor (success factors, opposed sentiments)

Citizens: REPLICATE provides easier ways of doing household chores and improves quality of life. SmartThings™ allows home owner to control their washing machine or tumble drier remotely. This removes the need to remain at home during laundry cycles. One can now place detergent and laundry in the washing machine, or wet clothes in the drier and go out. The smart phone control allows the device to be switched on remotely, from the supermarket, the gym, a friend's house etc.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

There is also the social value of comparing and contrasting technology, there is a certain 'wow factor' when explaining to your peers you are participating in a smart cities experimental initiative and contributing to a European wide project. Also, there is an impressive design quality to the devices, allowing home owners to showcase the latest technology at home.

BCC departments such as the Operations Centre, Highways, Energy Service, Traffic mgmt, city infrastructure, Open Data , and ICT will most likely be enablers for the platform. As will the development from Bristol is Open and REPLICATE partners such as Route Monkey, Universities & Research facilities, CoWheels.

Service operators and city asset managers can enable a better citizen engagement process

Obstacles are not yet realised, but could include the 'Middle-man' between sensors and end applications, being locked in to vendors and then find hidden specific sensor implementation details that don't align.

Working with commercial companies could also create issues. They may not want to support integration onto a potential future competitors' platform, may have technical officers all around the world, and be difficult to locate the necessary skills set especially as requirements change. It is not easy for SME's to re-imagine their development teams as a requirement change. Though the overall approach of multiple partners has had a lot of positive impacts due to the breadth of knowledge and approaches.

Competitors

Large tech companies offering Platform solutions

First findings and scale up analysis

Lessons learnt

Connections were incredibly difficult to maintain on all levels and were delivered in parallel. The citizens were being engaged right through the deployment phase and providing valuable input to what they wanted to see. All the partners were trying to develop their own applications to meet their own deliverables. In the middle of this was the development of the SCP. Assumptions were made and deployments were planned only to change, never fundamentally but always with a huge impact for the platform delivery.

The core learning has been two-fold. The development of any platform needs strong central ownership, not inflexible but able to manage the changes and deliverables in an agile framework. The actual interventions and the partners delivering them should be brought on board after the definition of the project has been thoroughly road tested with the users, be they citizens, councillors or other application developers. Running the definition alongside the delivery results in a form of retrospective agility where the platform is being re-built not redeveloped.

Optimal scale for next implementations

The final design of the SCP is the most portable and scalable. The platform can now take and store data from the platforms on the internet and those on local networks. FiWare enables the homogenisation of the data and the Open Data Platform as a showcase for the output. However, the

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

core part of the platform is the flexibility that means any of these components could be changed and re-engineered to meet a specific requirement.
The platform has drawn a lot of interest at exhibitions and during visits to BIO, UoB and BCC and will continue to be developed through its involvement in other projects, such as the Innovate UK funded Bristol Energy Smart System Transformation (BESST project)
The smart city platform currently supports 150 homes, connecting each via a virtual private network (VPN). The network controller can support several thousand VPNs.

Use case	Indicator	Measure
Smart Heating & Congestion	CO2 saved by not using heating wastefully	Remote triggering of heating via platform
Smart Heating & Congestion	CO2 saved by not using heating wastefully	Instances of advice given to reduce/stop heating based on ETA
Saving electricity bills using weather forecasts	££ saved by getting cheaper spot tariffs	Instances of advice given to stop/start appliances based on spot tariffs
Community solar projects	ROI of solar installations	Number of times calculators have been used
Lobbying for transport links	Community groups use analytics to argue to their areas	Number of times that Replicate analytics are used in consultations
Opportunities for new community assets	Community-identified opportunities to fill gaps in service provision	Times that citizens used Replicate platform, capabilities, apps or analytics to establish new community assets
Analytics-driven energy policy	Changes to energy supply policy based on analytics	Qualitative feedback on data products derived from platform analytics by policymakers

This architecture could be replicated and rolled out to other smart cities. The connectivity between white goods and the cloud is VPN over home Wi-Fi but could be carried over any wireless access point. Replicability to addition electrical appliances within connected homes is also possible, by increasing the number of smart plugs.

Further developments needed

Not available yet

Expected impacts

For the purposes of platform impact measurement, we propose to only focus on services comprising the core FiWare broker, the Energy Demand Management System (EDMS) and the Zeetta Software Defined Network (SDN). Even at such a core infrastructure layer, however, our focus must be on how the platform enables our wider goals and not on simply measuring traffic, code or processor time used; our platform must be judged against its purpose.
Ideally in the future we want a SCP that is an intuitive system that is able to understand dependencies and provide a system with a 'if this happens, then that is triggered' approach. The impacts of this will be a far more efficient and smarter city that is responsive for citizen services.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Solution 8: Big Data for mobility services

Main partners involved: Euskaltel, Tecnalia, Fomento San Sebastián, ADS (Municipality of San Sebastian)

Short description of the action:

Big Data are more and more useful to guarantee a higher quality in services of interest for cities and telecommunication companies.

The urban mobility patterns are a critical task for transportation planning and management in the cities. Traditional methods, such as household or street surveys, although they provide detailed information, are slow and costly processes for the acquisition and analysis of information, preventing the possibility of generating transport demand models with the desired frequency and quality.

A large amount of geo-located data can be collected over time through mobile telephony and with high representativeness. In addition, the traces associated with a private WiFi service are also integrated to improve the accuracy and success of the algorithms. Based on the data managed by the biggest operator in the Basque Country, EUSKALTEL, advanced data analytics methods can provide very exact aggregated information about mobility of people in the city as mobility heat points, origin-destiny matrix, etc.

In the project framework, value of the information has been contrasted, to improve real-time knowledge of urban mobility in San Sebastian pilot. To achieve this goal, a Data Lake, the Big data

infrastructure built to store and transform the data coming from the network into people movement information, and a set of mobility analytics algorithms, have been developed, defined to extract aggregated information. Additionally, an Application Program Interface for the information of the third parties (in this case, San Sebastian Municipality) is now available.

The area selected for the pilot action is Donostialdea.

Value proposition

The aim of the project is to collect the most reliable data on mobility behaviours in San Sebastian in order to plan the most suitable actions in the transport sector, so to reduce operating costs in services and optimally coordinating resources, anticipating problems and future trends and disseminating useful information to citizens.

The most common methods for gathering information on mobility behaviour were in fact interviews, questionnaires and surveys, all of them facing a number of limitations relating to its accuracy, representativeness and reliability. Replicate proposal is to obtain an aggregated characterization of urban mobility based on operational information from mobile network companies. Analytics of this data can provide very exact information about means of transport, origin-destiny matrix, etc.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Technology

In this section, the analytics algorithms to compute aggregated Origin-Destination (O/D) Matrixes is described. These matrixes are an aggregated representation of the mobility patterns within the city of San Sebastian and basically store the number of displacements that have occurred within different sectors of the city. The matrixes are computed every 30 minutes which allows representing the mobility taking in to account the time of the day.

Different types of data are considered to generate the O/D matrixes. Specifically, the following information is considered:

- The Call Detail Records (CDRs) which stores details of the data sessions as the type of a connection and its duration. In the case of Replicate the user id, the serving base station id and the hour of the day at which the connection is performed are used. These data constitute the largest part of the data used.
- Euskaltel "WIFI Kalean" data. WIFI Kalean is a service that allows Euskaltel clients to share their WIFI spots, splitting its WiFi in two parts; one private for their own use, and another public, shared between all the customers of Euskaltel. The clients who use this service share the usage of the routers with the rest of the users in such a way that a user can use a router placed in some other user home in a transparent way. In this case we use the MAC of the WIFI, the user id and the hour of the connection.
- Localization of the base stations and WIFI routers. These data allow locating the users to be able to estimate their trips.

All these data are store in HDFS filesystem using and HBASE database in such a way that the information can be processed in parallel. The processing of the data is performed using the Map-Reduce paradigm which follows the diagram shown in the figure below. In this Figure a big pool of data, labelled as Big Data stores all the records to be processed. In the case of the Replicate project this is realized using an HBASE HDFS distributed data base.

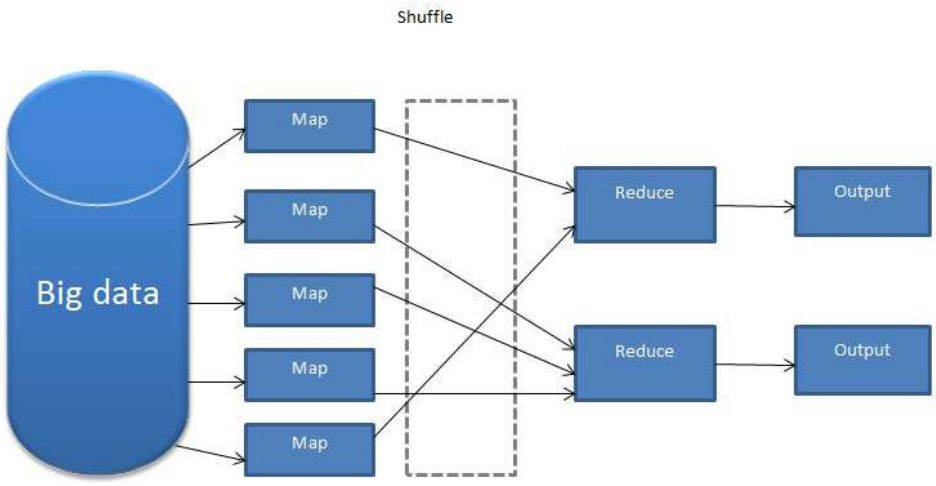


Figure 9.27 – Structure of the Map-Reduce Procedures

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

A user that is connected to a base station is located in the zone of influence of its antenna. The specific zone of influence is difficult to determine because the exact extension covered by a base station depends on many different factors. Orography, buildings in the area, the actual power of the antenna and even the weather have a crucial impact on the exact delimitation of the zone of influence. As solution, the Voronoi diagram is adopted, a tessellation of the map in polygons in such a way that all the points within a polygon are closest to a specific antenna.

The collected data are cleaned from jumps, not representing real transitions from different zones, and trips are computed: a trip is considered as a set of connections with base stations or WIFI Kalean routers of the same mobile device which are temporally ordered, a displacement is produced, and consecutive measurements are not distant apart in time.

The data trips collected are aggregated in the matrix and elaborated. The results are represented in a map:

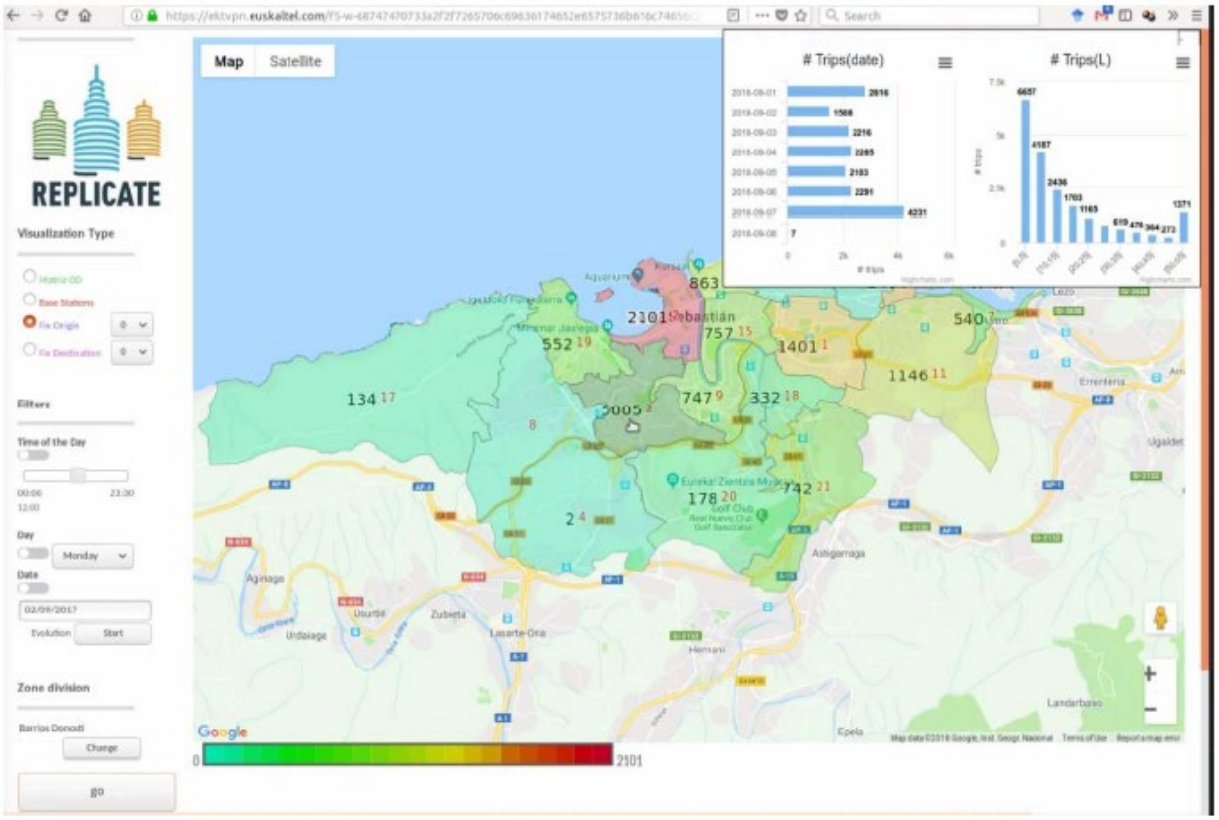


Figure 9.28 – Map example

An Application Programming Interface has been defined and agreed with the Municipality, to export calculated diagrams and reports.

Euskaltel is able to provide mobile services for both its residential and business customers. Euskaltel is the largest MVNO (Mobile Virtual Network operator) in Spain. The core network of the company currently supports GSM, UMTS, HSPA and LTE services. Services are offered under the full MVNO model for both current technologies.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

In order to implement the Full MVNO model, because of the nature of these networks, Euskaltel has been provided with the entire necessary infrastructure to allow for a complete control of the customers, except for radio access. This network enables the phone services offered to all mobile customers in a virtual mobile network operator according to the "Full MVNO" model.

In order to be able to face the challenge of storage and treatment in pseudo real time, that is from logs, HortonWorks HDP 2.4 has been installed in the Euskaltel DataCenter.

Innovation Level

The use of Call Detail Record – CDR data for mobility analysis is of increasing interest to the transport planning agents; here, the potential to use CDR data to underpin mobility analysis significantly advances the trend away from time consuming and/or resource intensive techniques. Repurposing CDR data provides several advantages: unparalleled scale, coverage, spatial granularity and temporal accuracy. Although, the processes stages and supporting architecture needed in the exploitation of operational are known, the main innovation and success of the proposed work are due the data richness and large coverage of Euskaltel in the pilot geographical scope. Specifically, the composition of trajectories manages the fusion of complementary CDR and WiFi Kalean data.

Additionally, another innovation relies in the fact that without deploying additional infrastructure for sensing, the information provided included both vehicles and pedestrian, those last, very difficult to be monetarized with other sensing techniques.

Direct impacts

Municipal planners can benefit of a great quantity of reliable data and information (processed by the Mobility Platform), on which they can base decisions and improving so the quality and effectiveness of the interventions and initiatives adopted.

Indirect impacts

A good understanding of the demand and mobility needs in the city, contrasted with the current transport offer, will identify neighbourhoods or areas with particular needs.

Furthermore, the possibility of aggregating mobility information allows a continuous monitoring of the Urban Sustainable Mobility Plan indicators, giving the possibility to adopt corrective/improving actions and improve therefore urban sustainability, in environmental, social coexistence and economic terms. Lastly also SMEs will have access to citizens and tourists transport behaviours data. With this information SMEs can implement performances more attractive for tourists, offering promotions, and they can measure the impact of their marketing campaigns.

Market analysis: enablers and obstacles

Legal framework

The main regulation related with the analysis of location based in mobile devices is the General Data Protection Regulation (EU) 2016/679 ("GDPR"). This is a regulation in EU law on data protection and privacy for all individuals within the European Union (EU) and the European Economic Area (EEA).

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

According to this regulation, a Privacy Impact Assessment (PIA) has been carried out in Euskaltel to ensure the absence of risk of privacy loss for the end users.
There are also other two regulations related to the project:
• "Norma Técnica de Interoperabilidad de Reutilización de recursos de la información" (BOE-A-2013-2380). It defines the URIs and compulsory metadata (DCAT based schema) for resources published by official institutions.
• "Ciudades Inteligentes. Datos Abiertos (Open Data)." (UNE 178301:2015). It defines the technical requirements for the Open data provided by an intelligent city. It provides a scale to assess the compliancy level of a given city.

Incentives: None

Human factor (success factors, opposed sentiments,…)

As explained before, the main success of the proposed work is due the data richness and large coverage of Euskaltel in the pilot geographical scope and the possibility to gather information about pedestrians and private vehicles movements in a no-intrusive way and without deploying additional infrastructure.

As for the critical aspects, currently an annual data consolidation is carried out, with insufficient frequency to assist in the operation. The information is not exploited in a coordinated way, data sources are not merged, they are treated separately, so it is even difficult to assess whether the information that is already available is sufficient or not. Additionally, only vehicular information, conventional traffic sensory information and transactional public transport information were addressed.

Competitors

Other telecommunication operators can provide similar information, if they develop similar platforms, but up to know, Euskaltel is the only Telecomunication operator in the Basque country that provides public WiFi, which provides more accurate localization.

First scale up analysis:

Lessons learnt

The data collected through mobile network companies have some advantages compared to traditional methods: a non-intrusive capture of information, there is no active participation of citizens, the data collected are not subject to subjective interpretations, a diagnosis of global mobility regardless of the mode of transport used and the availability to obtain a large amount of geolocated data over time with a high representativeness in the study area, Donostialdea.

Optimal scale for next implementations

Any scale is possible.

Further developments needed

Euskaltel's intention is to improve and enriching its mobile services offer, improving its integration with other Euskaltel's services in a landline-mobile convergence scenario.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

In this first phase of the project, the movement matrix is calculated every 30 minutes, while Euskaltel can accurate it until near real time, updating information every 5 minutes approximately. A new research/development could face the optimisation of the calculation period, in order to extract the most various information according to applications developed based on this information. Different applications may request different matrix periods.

Expected impacts in the next future

Thanks to the collected data more effective mobility actions will be promoted by the Municipality of San Sebastian and new more efficient actions will be adopted by the mobility services operators, increasing the final users' satisfaction.

Solution 9: Linked Open Data

Main partners involved: Eurohelp, Fomento San Sebastián, ADS (Municipality of San Sebastian)

Short description of the action

The publication of interoperable and rich Open Data is paramount for the citizens to truly take advantage of the Smart City solutions deployed in San Sebastian.
Eurohelp has designed, developed and deployed the Open Data platform to publish the data resulting from different Smart City realms, in traditional, file based Open Data (Open Data Portal) and in the Linked Open Data system. DonostiaTIK has provided the hosting machines for the platform. Fomento San Sebastián has coordinated the collaboration between Eurohelp and the San Sebastian municipality, in order to gather requirements, design and deployment of the platform.

Value proposition

The publication of high quality, rigorous, and up to date Open Data in non-proprietary formats, with open licenses like Creative Commons BY 4.0, adds a substantial value to the smart city, allowing:
1) Ease of access for citizens, in order to reuse the data, remain informed in real time, and assess the activity of the city council through deep analyses.
2) Ease of access for machines, in order to improve the discoverability of the data, and the creation of sophisticated applications and services by 3rd parties. This is specially the case for the Linked Data system.

Technology

The solution in use:

The technology used for the Open Data platform comprises:

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

- W3C standards for data modelling, knowledge representation, data analysis and querying. In particular RDF and OWL are used for the screening, encoding and exchange of contents; SHACL provides graph-based data authentication and SPARQL allows us to interrogate database.
- CKAN (FIWARE enabler) to manage storage, as the implementation for the file based Open Data Portal.
- Blazegraph as the Triple Store for storing the RDF generated from the files of the Open Data Portal.
- Jenkins as the pipeline manager for executing the batch processes that generate de RDF data from the Open Data portal.
- Grafter, RML.io, and tailored Java programs for the conversion of the CSVs to RDF.
- ALDAPA (Assistant for Linked Data Production Automation), developed by Eurohelp, for metadata management and RDF conversion pipeline generation.
- A SHACL-based data validator, developed by Eurohelp, to ensure data quality, consistency, and Linked Data best practices.
- SILK for link discover
- Linked Data server, developed by Eurohelp, to serve RDF data as a result of Content Negotiation or SPARQL queries posed by machines
- ELDA to serve HTML renderings of RDF data, as a result of Content Negotiation
- YASGUI to offer a graphic form for humans to pose SPARQL queries
- Docker (FIWARE enabler) as the deployment environment

As a result of using the above technology the innovation level achieved by Eurohelp and DonostiaTIK is considerable, since these technologies represent the forefront of the Semantic Web, Graph-based solutions, structured data APIs, and container-based microservice architectures.

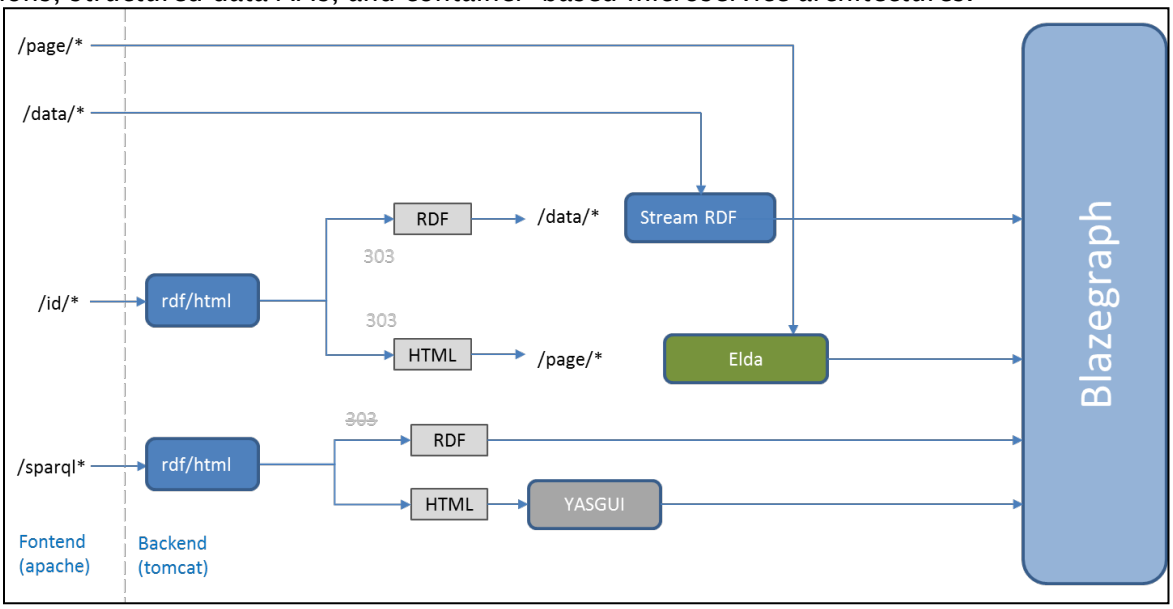


Figure 9.29 – high level architecture of the public-facing Linked Open Data server.

Linked Data resources are served on URIs following the pattern base/id/*, and content negotiation is performed to serve the appropriate representation for each client. SPARQL queries can be performed

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

on URIs following the pattern base/sparql/*, by automatic agents or human users (through a web form). The applications serving the data connect to the Balzegraph instance to obtain it.

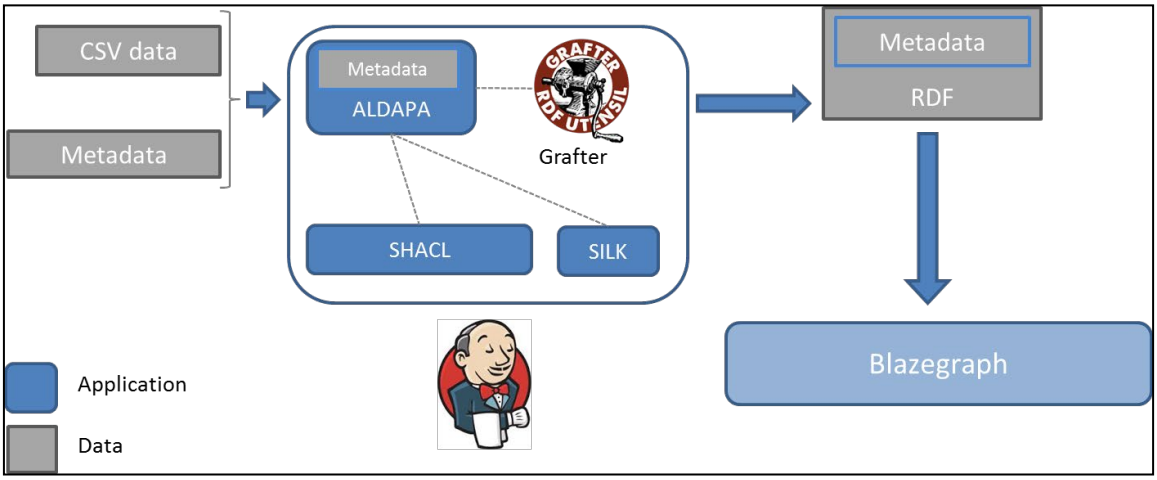


Figure 9.30 – internal pipeline for producing Linked Open Data.

Figure 9.31 – details of a pipeline, executed by Jenkins.

Main impacts of the measure (economical, environmental, social):

Direct impacts

The direct impacts of the Open Data platform for San Sebastian comprise:

- The foundation stone in San Sebastian's Open Data road.
- The city of San Sebastian gets visibility by appearing in the list of participating cities in the Open Data community.
- Selected datasets are made public and accessible for anyone and anything (agents, machines).

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

•Published data becomes linked to other International Linked Data resources, augmenting the serendipitous discoverability of the published data.
•Transparency increases as well as its assessment by the citizens.
On the other hand, the direct impacts for Eurohelp comprise:
•Valuable knowledge for a new business line. Linked Data is quickly becoming a profitable sector, since governments are using it to publish Open data, but also companies are using it internally to connect "Data Silos". Therefore, the experience acquired by Eurohelp developers in developing and deploying San Sebastian's Open Data platform will be vital for expanding Eurohelp's business offerings.
•Eurohelp is currently building other Linked Open Data platforms.
•All the tools and pipelines produced by Eurohelp are Open Source and available in GitHub, contributing to the community.

Indirect impacts

The indirect impacts include the ability of the city managers to assess the state of the city through Linked Open Data and build more sophisticated analysis tools.

Market analysis: enablers and obstacles

Competitors

Linked Open data technology offering is growing, and there are some companies that offer services analogous to Eurohelp. Most notably, GNOSS has been contracted by the Government of Aragon to build a full Linked Open Data solution for the Aragon Open Data portal, similar to the Linked Open Data solution built by Eurohelp.

Legal framework & incentives

There two main regulations related to Linked Open Data in the Spanish context:

- "Norma Técnica de Interoperabilidad de Reutilización de recursos de la información" (BOE-A-2013-2380). It defines the URIs and compulsory metadata (DCAT based schema) for resources published by official institutions.
- "Ciudades Inteligentes. Datos Abiertos (Open Data)." (UNE 178301:2015). It defines the technical requirements for the Open data provided by an intelligent city. It provides a scale to assess the compliancy level of a given city.

Human factor (success factors, opposed sentiments,…)

Citizens perceive the improvements due to Linked Open Data publication in a long-term, indirect way. An information campaign on the advantages of Linked Open Data, by DonostiaTIK, would be helpful.

First scale up analysis

Lessons learnt

Linked Open Data is based in two notions that are difficult to grasp: Resources identified by URIs and Graphs. This means that deployment is challenging, since staff with no experience on those domains

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

will have difficulties adapting to the new paradigm. Also, the main advantage of a Linked Open Data solution (Interoperability with other datasets) can only be perceived in a very long term (5 to 10 years).

Optimal scale for next implementations

Any scale is possible, given that the appropriate computational resources are assigned. It is important to notice that Amazon has released Neptune, a fully managed graph database service for RDF, SPARQL, Property Graphs and Gremlin, offering a very scalable, easy to use solution for implementing Linked Open Data systems backed by High Availability Triple Stores.

Further developments needed

More robust, enterprise ready tooling for the production of RDF from disparate formats, and tools for entity reconciliation and URI management.

Expected impacts

with regards to society, a richer citizen participation in smart city processes results from the publication of Linked Open Data. Companies also benefit, since they can build sophisticated services on top of Linked Open Data. Moreover, the use of Linked Open Data in institutions creates a Linked Data ecosystem that opens up new paths to local companies that otherwise would not invest in Linked Data technologies that, to some extent, are still experimental.

Comparison of the different solutions and approaches

Infrastructures

The two solutions analysed present a quite different nature but both of them allow further services and prepare the ground for a smarter environment.

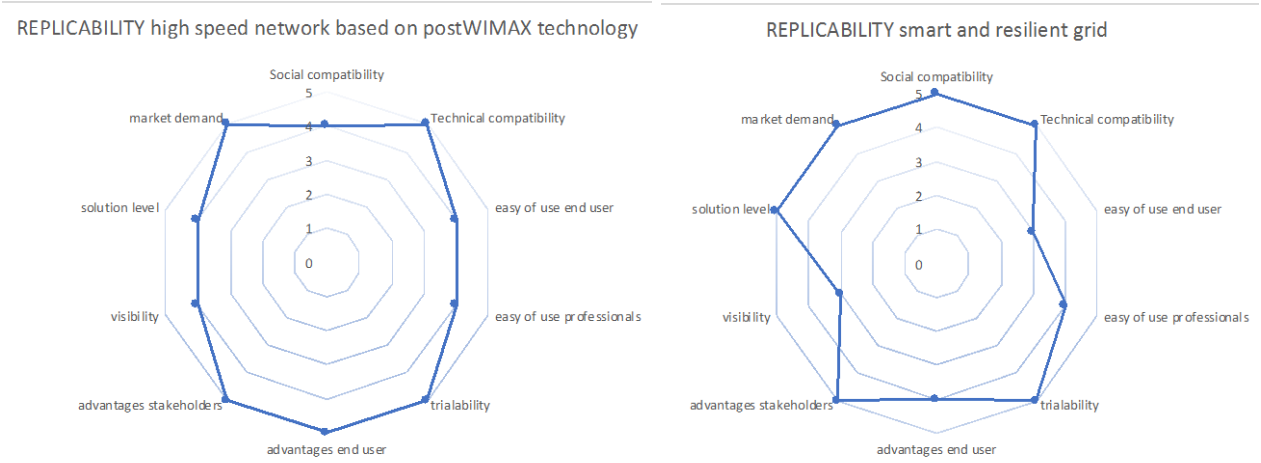


Figure 9.32 comparison among the different solutions of smart infrastructures

The two infrastructures have very high values for technical compatibility, advantages and market demand. The remaining values are also very good even if the smart grid remains hidden to the wide

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

public (a video has already been provided to support information and dissemination) and it is more dedicated to professionals and service providers than to final consumers.

Smart Lighting

The lighting systems deployed are matching efficiency measures with additional control and smart services nevertheless it seems that the two trials have had different results in the two cases maybe because of the nature of the partners involved or of the services provided: private company could have experienced more obstacles for the implementation while a municipal third party could have been more skilled in public procedures; the information campaign also could have played a significant role highlighting advantages to stakeholders and end users. Moreover, the provision of additional services, even if complex for the design and the professionals, has resulted much easier in the deployment because of administrative and economic advantages.

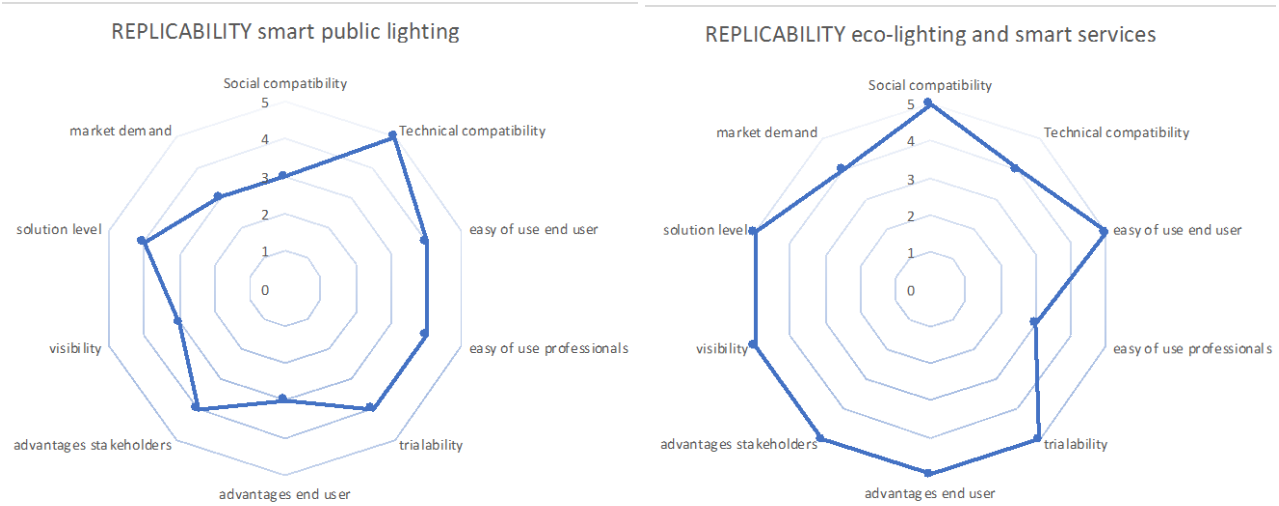


Figure 9.33 comparison among the different solutions for smart public lighting

The market demand for efficient lighting is high at the moment, but it must be said that the transformation into LED must be exploited quickly by smart services, because when the LED lights will be already in place and should be just replaced, energy and money savings will be more and more difficult to achieve only with control systems and it will make the business models of the whole package less attractive.

ICT Platforms

The four ICT platforms developed present in general a good profile for replicability: they are solutions for common needs for smart cities, with a high technological compatibility and a possibility of small-

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

scale trials. The advantages for stakeholders and users are different, but in general those solutions can be tailored on their needs after a tuning period.

Figure 9.34 comparison among the different solutions of ICT platforms

One aspect that can be optimised is the user-friendliness both for professionals and for end users as well as the visibility being a municipal asset with direct impacts/benefits on daily life but with a hidden infrastructure, except for the citizens' platform.

Data solutions

Regarding data management, the two options have different purposes and impacts but both present a similar profile (5 peaks on 10) with good but optimisable values typical of trials. The issues targeted are common to most of the advanced cities and linked to the ICT platforms diffusion; their scale up and replication potential therefore is quite high, but some aspects have to be still increased (social compatibility, easy of use, clear advantages, …)

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

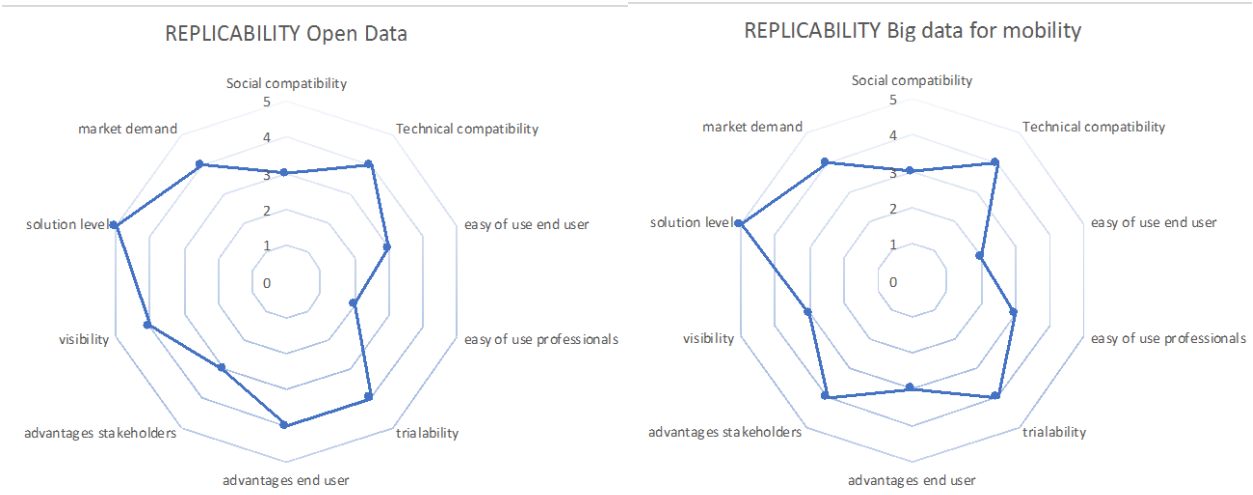


Figure 9.35 comparison among the different data solutions

10. Replication and impact analysis

This deliverable, together with D7.5 which illustrates the management models of the interventions, is aimed at providing a full analysis of the main actions detailing some aspects which could influence the scale-up and the replication options.

The lessons learnt and the first assessment of the implementations, made through graphics and KPIs, are supporting the decision-making process in the planning activities of the three lighthouses for the roll out plans and of follower cities for replication plans. Being public, those documents are meant to inspire also other interested cities, for example those involved in the national Advisory boards; the methodology adopted, colliding different approaches developed in the project (WP2,7,9,10) could also be easily disseminated and re-used.

Not only cities can benefit from the experience exchange and disclosure of info, but also companies and SMEs could take advantage of the results collected and first evaluations.

Nevertheless, the cross-cutting activity itself, except for the methodology adopted and the possible cross-fertilisation among the cities involved, is not directly impacting on the overall innovation or environmental results of the pilots but it will influence the roll out.

In the following paragraph the innovation, the social-environmental-SMEs impact and the replicability of the different solutions investigated are summarised to provide an overview at this stage of the project.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Innovation solution

All the measures selected to be part of this deliverable present innovative aspects that have been highlighted in the previous descriptions. Hereafter are summarised the main innovative features for each group of interventions.

· DISTRICT HEATING

The innovation level of the systems is high for UK and although tested in other countries, these developments are the first of their kind in the Basque Country or in Italy where the solar TES implementation could be the first attempt for South Europe.

· ENERGY DEMAND MANAGEMENT

Regression machine learning techniques, based on big data processing algorithms, allow to decouple from the physical grounds and to come up with operation decisions that can be dynamically and continuously improved. Furthermore, it has been established connectivity between IOT devices (such as smart appliances, electric car charging points and smart meters) in order to monitor and control, through a FIWARE based Smart City Platform, energy demand within the city with highly innovative techniques.

NEC has also developed an innovative and highly sophisticated approach to modelling the behaviour of a large number of independent energy consumers.

· NEW E-TAXI MODEL

The e-taxi measure with the municipality driving the transition to an e-fleet through new licences, a dedicated innovative fast infrastructure, innovative services (booking APP), facilitations (cheap e-licence, agreements with e-vehicles producers, e-service priority) is proving an innovative scheme, highly replicable.

· CHARGING POINTS AND E-BIKES

The deployed e-bike monitoring system has a number of smart aspects and Replicate is providing smart real time reporting functionality for e-bikes through a series of innovative additions to the Co-wheels system. Lastly, thanks to the FIWARE functionality of the Smart City Platform it is possible to connect to e-bikes and EV charge points.

· SMART MOBILITY SUPPORTING SYSTEMS

While detecting parking using a smartphone is not new, the novel aspect in the case of ParkUs is automatic cruise detection using sensor and location data and a parking availability inference system which requires minimal user interaction.

The Replicate one will be the first Journey Planner developed for Bristol which will successfully combine in an intelligent way all of the following when calculating journey options: Car Parks, Cycling, Rail, Bus, Walking, Driving and Park and Ride locations.

· INFRASTRUCTURES

The POST WIMAX technology implemented in the REPLICATE project on the WiFi network enables high range and coverage thanks to the implementation of technical solutions previously used in DTT (Digital Terrestrial Television) Military and Critical Mission networks: the innovation comes from adapting it for Broadband networks at a competitive price in urban areas.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

The Smart Grid solution implemented in Florence is highly innovative optimising resilience and service quality requirements and enabling the development of other innovative services like e-mobility, smart-metering&EDMS, etc. For example, thanks to the development of a new advanced automation for the automatic detection and isolation of a fault in the grid (SFS –Smart Fault Selection), it is possible to reconfigure the grid in a faster way, improving service quality and reducing energy outages.

· SMART PUBLIC LIGHTING SYSTEMS

The use of an open source system that provides its data to the ICT platform enables to take decisions, as the adaptation of light levels and its operation to the real needs of the moment. Also, the Smart lighting system integrates several other services spread in the district optimising the use of the infrastructure together with energy efficiency led system. This first experience can be translated in other urban areas with the same control needs.

· SMART PLATFORMS AND RELATED SERVICES

The innovation comes from the experimentation of different modules developed with open software to create innovative architectures with exchange and responsive opportunities among different subsystems. Moreover, the Smart City Control Room solution presents a unique multi-level governance model (Firenze Digitale) which is paving the way for a successful collaboration among utilities, Fire and Rescue services and the Municipality (win-win solution).

· LINKED OPEN DATA

Thanks to the activities done under REPLICATE project, a new software has been designed and developed that helps in the complex Linked Open Data generation process.

Social impacts

· BUILDINGS EFFICIENCY (DH, EDMS): residents' engagement enhanced participation and social inclusion, quality of life and comfort have been increased

· BETTER CONNECTIVITY: easier connections and more services are available to citizens, awareness rising and capacity building are indirect impacts

· INTELLIGENT PUBLIC LIGHTING: the main impact is the reduction of energy bills for the collectivity, but also the increased security and the additional services has provided significant social impacts.

· IMPROVEMENT ON URBAN MOBILITY: mobility platforms and multimodality can speed up people's travels, pollution and noise savings are further important impacts together with benefits on health due also to active mobility. The availability of new services for vulnerable people (i.e. disabled, women, etc) is overcoming mobility barriers. The sharing solution improves the social inclusion as it allows the access to cars and e-bikes without the expense of ownership.

· ICT PLATFORMS AND DATA: Platforms enhance cooperation and stakeholders' participation. They present many indirect impacts on daily life and support the awareness rising.

· ENGAGEMENT ACTIVITIES: empowerment of citizens to use technology and by using it.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Environmental impacts

Environmental impacts will be assessed and monitored during the next two years following the implementations, but they have been estimated during the design of the actions.
Buildings retrofitting and district heating systems feeded with renewable sources will save primary energy and emissions as foreseen in the BEST tables and reported in the measures description.
Thanks to electric mobility, beside the pursued energy saving and GHG savings, the overall air quality will be influenced as well as the noise pollution.
Environmental and consumption data will be collected and monitored also through the city platforms and the IoT providing detailed maps and trends: ICT measures support direct impacts due to wise regulation&control of power and heat plants and more indirect impacts linked to data collection, analysis and monitoring.
In the following tables the main environmental impacts are reported:

Buildings	
District Heating (solution 1,2 3)	Thanks to the DH projects integrating RES (biomass or solar) along with optimized control strategies, CO_2 emissions will be reduced between the 50% and the 80% compared to individual heating and hot water systems. In San Sebastian for example the new DH within a period of 20 years would lead to a reduction of almost 50.000 CO_2 tonnes
EDMS (solution 4,5)	Thanks to the EDMS it is expected that consumers become more rational energy users, which means a reduced environmental impact, improvement in air quality and lower energy demand pikes.
Mobility	
e-taxi fleet (solution 1)	During the project lifetime at least 100 e-taxis will start the service with an average yearly saving of -200 CO_2t/y
Charging points and e-bikes (solution 2,3)	The pilot in Bristol results in fewer combustion engine vehicles in circulation and less traffic with benefits for the environment and for the liveability of the city. For example the CO_2 saved is 0.36 tonnes per e-bike per year
Smart mobility supporting systems (solution 4,5)	The smart mobility APPs should contribute in decongesting traffic and supporting multimodality. ParkUs app for example aims to reduce a major portion of cruising emissions in the pilot area (estimated over 790 metric tons of CO_2)
ICT & infrastructures	
Smart infrastructures (solutions 1, 2)	Many other actions will benefit from these new infrastructures: the data availability will influence user's behaviour and will allow detailed analysis to support decision making processes; with the smart grid in

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

	particular, the distributed production of energy will be supported as well as e-mobility implementation
Smart lighting (solutions 3, 4)	Both the actions will reduce the energy consumption of the public lighting network (and the GHG emissions) and the related costs. From the first monitoring in San Sebastian, the reduction in kWh consumption comparing same months has been of 69% while in Florence the actual consumption in the district is about 4,5 GWh/y, and the foreseen consumption will be of 2,6 GWh/y (savings > 40%) i.e. 650 CO_2t/y saved.
Smart Platforms (solutions 5,6,7,8) and data management (solutions 9, 10)	Platforms are collecting and connecting data to support city management. It is a shift of approach to the management of services, that also brought as a positive outcome a stricter cooperation among different technical departments of the Municipality that previously were working more as vertical silos. Platforms enhance cooperation and stakeholders' participation, as in the case of citizens platform, and their indirect impacts can be environmental due to the possible consumption savings in the different sectors monitored (buildings, mobility and services like watering and waste collection).

Replication and scalability potential

The replication potential has been assessed with the Citykeys methodology: the propagation KPIs for smart city projects have been evaluated for each of the actions reported.
For the Likert scale we decided to standardise the answers with the following set of options so that they could be weighted: 5. Excellent/high, 4. Good, 3. Average, 2. Poor/low, 1. Not acceptable/very low. For a detailed description of each KPI and the guide for the assessment see annex2

Buildings

Citykeys KPIs scalability	Definition	New DH	Upgraded DH	Storage & DH	Energy Demand Manag.	Smart H&M EDMS
Social compatibility	The extent to which the project's solution fits with people's 'frame of mind' and does not negatively challenge people's values or the ways we are used to do things.	3	3	3	4	4
Technical compatibility	The extent to which the smart city solution fits with the current existing technological standards/infrastructures	4	4	3	5	5
Ease of use for end users of the solution	The extent to which the solution is perceived as difficult to understand and use for potential end-users	3	3	4	2	2

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Ease of use for professional stakeholders	The extent to which the innovation is perceived as difficult to understand, implement and use for professional users	3	4	3	3	2
Trialability	The extent to which the solution can be experimented with on a limited basis in the local context before full implementation	1	2	3	4	4
Advantages for end users	The extent to which the project offers clear advantages for end users	5	5	4	4	4
Advantages for stakeholders	The extent to which the project offers clear advantages for stakeholders	4	4	4	4	4
Visibility of Results	The extent to which the results of the project are visible to external actors	4	Too soon	4	3	3
Solution(s) to development issues	The extent to which the project offers a solution to problems which are common to EU cities	4	5	5	5	5
Market demand	The extent to which there is a general market demand for the solution	2	3	3	4	4
Citykeys KPIs success	Definition	New DH	Upgraded DH	Storage & DH	Energy Demand Manag.	Smart H&M EDMS
Changing professional norms	The extent to which the project changes the professional 'state of the art'	3	5	5	5	4
Changing societal norms	The extent to which the project changes the norms and values of the society	3	3	3	4	4
Diffusion to other locations	The extent to which the project is copied in other cities and regions	4	Too soon	Too soon	3	3
Diffusion to other actors	The extent to which the project is copied by other commercial parties	3	Too soon	Too soon	4	Too soon to report
Change in rules and regulations	The extent to which the project has contributed to changes in regulations	1	3	3	3	3
Change in public procurement	The extent to which the project has inspired new forms of public procurement procedures	4	Too soon	3	3	Too soon
New forms of financing	The extent to which the project has inspired the development of new forms of financing	2	Too soon	3	4	Too soon
Smart city project visitors	The number of visitors to the project site or to the website	3	n/a	Too soon	3	3

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Mobility

Citykeys KPIs scalability	Definition	e-taxi fleet and fast recharge	Charging points	e-bikes	ParkUs	Multimodal journey planner
Social compatibility	The extent to which the project's solution fits with people's 'frame of mind' and does not negatively challenge people's values or the ways we are used to do things.	5	3	4	4	4
Technical compatibility	The extent to which the smart city solution fits with the current existing technological standards/infrastructures	3	4	4	4	4
Ease of use for end users of the solution	The extent to which the solution is perceived as difficult to understand and use for potential end-users	5 (citizens)	3	2	4	3
Ease of use for professional stakeholders	The extent to which the innovation is perceived as difficult to understand, implement and use for professional users of the solution	3 (taxi drivers)	2	2	4	3
Trialability	The extent to which the solution can be experimented with on a limited basis in the local context before full implementation	5	4	4	4	4
Advantages for end users	The extent to which the project offers clear advantages for end users	5	5	4	4	3
Advantages for stakeholders	The extent to which the project offers clear advantages for stakeholders	4	4	3	4	4
Visibility of Results	The extent to which the results are visible to external actors	4	5	4	4	4
Solution(s) to development issues	The extent to which the project offers a solution to problems which are common to European cities	5	5	5	4	3
Market demand	The extent to which there is a general market demand for the solution	4	5	3	3	4
Citykeys KPIs success	Definition	**FI e-taxi fleet and fast recharge**	**Charging points**	**e-bikes**	**BCC ParkUs**	**BCC Multimodal journey planner**
Changing professional norms	The extent to which the project changes the professional 'state of the art'	4	4	4	5	4
Changing societal norms	The extent to which the project changes the norms and values of the society	4	4	4	3	4
Diffusion to other locations	The extent to which the project is copied in other cities and regions	4	4	4	NA	4

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Diffusion to other actors	The extent to which the project is copied by other commercial parties	NA	4	3	NA	4
Change in rules and regulations	The extent to which the project has inspired changes in regulations	3	3	2	NA	3
Change in public procurement	The extent to which the project has inspired new forms of public procurement procedures	2	2	2	NA	3
New forms of financing	The extent to which the project has inspired the development of new forms of financing	2	3	2	NA	3
Smart city project visitors	The number of visitors to the project site or to the website	5	3	n/a	NA	3

ICT & CITIZENS ENGAGEMENT

Citykeys KPIs scalability	Definition	High Speed net. Post WIMAX	Smart Grid	Smart public light	Eco Light & smart services	Smart Mobility plat.	Citizens particip ation plat.	SCCR	ICT plat.	Linkd Open Data	Big data for mobility
Social compatibility	The extent to which the project's solution fits with people's 'frame of mind' and does not negatively challenge people's values or the ways we are used to do things.	4	5	3	5	5	4	4	3	3	3
Technical compatibility	The extent to which the smart city solution fits with the current existing technological standards/infrastructures	5	5	5	4	4	4	5	5	4	4
Ease of use for end users of the solution	The extent to which the solution is perceived as difficult to understand and use for potential end-users	4	3	4	5	3	3	3	2	3	2
Ease of use for professional stakeholders	The extent to which the innovation is perceived as difficult to understand, implement and use for professional users of the solution	4	4	4	3	4	2	4	2	2	3
4Trialability	The extent to which the solution can be experimented with on a limited basis in the local context before full implementation	5	5	4	5	4	4	4	5	4	4

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Advantages for end users	The extent to which the project offers clear advantages for end users	5	4	3	5	5	4	4	4	4	3
Advantages for stakeholders	The extent to which the project offers clear advantages for stakeholders	5	5	4	5	4	3	5	4	3	4
Visibility of Results	The extent to which the results of the project are visible to external actors	4	3	3	5	3	4	3	3	4	3
Solution(s) to development issues	The extent to which the project offers a solution to problems which are common to EU cities	4	5	4	5	4	5	5	5	5	5
Market demand	The extent to which there is a general market demand for the solution	5	5	3	4	4	4	5	3	4	4
Citykeys KPIs success	Definition	High Speed net. Post WIMAX	Smart Grid	Smart public light	Eco Light & smart services	Smart Mobility plat.	Citizens particip ation plat.	SCCR	ICT plat.	Linkd Open Data	Big data for mobility
Changing professional norms	The extent to which the project changes the professional 'state of the art'	4	4	4	4	4	NA	5	4	5	5
Changing societal norms	The extent to which the project changes the norms and values of the society	2	3	3	3	4	NA	3	NA	5	4
Diffusion to other locations	The extent to which the project is copied in other cities and regions	3	Too soon	5	4	3	NA	5	Too soon	4	3
Diffusion to other actors	The extent to which the project is copied by other commercial parties	4	Too soon	5	3	3	NA	5	Too soon	4	3
Change in rules and regulations	The extent to which the project has inspired changes in regulations	3	4	3	3	2	NA	3	Too soon	3	3
Change in public procurement	The extent to which the project has inspired new forms of public procurement procedures	2	NA	3	4	2	NA	4	Too soon	3	2
naNew forms of financing	The extent to which the project has inspired the development of new forms of financing	3	NA	4	3	2	NA	3	2	3	3
Smart city project visitors	The number of visitors to the project site or to the website	3	NA	NA	4	2	NA	5	NA	3	NA

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement Nº 691735

Economic feasibility

The economic feasibility of most of the actions reported together with additional measures included in the three pilots has been analysed in detail in deliverable D7.5 "Report on management models v2": after a detailed description of the business related aspects of the actions, the management models in use have been described and studied through a Swot and USP methodology; a first attempt for the extension of the actions after the pilot test has been developed together with the lighthouses and the involved partners through the definition of a possible future management model.

Impact on SME´s

The co-productive approach implemented by the three lighthouse cities since the planning phase of their Smart City concept (FP7 Steep project – www.smartsteep.eu) allowed a wide engagement of stakeholders and players from different sectors and of different size. Several SMEs are involved in the pilots to test innovative approaches and technologies. They can benefit from the possibility of implementing new business and also from the support and knowledge exchange in cross-cutting activities of a wide international consortium made of public authorities and companies, big players, universities and research centres.
The partner SMEs involved in the reported actions are:
· SISTELEC: Sistelec is specialized in wireless communication of voice, video and data, for both indoor and outdoor applications. The opportunity to take part in REPLICATE project, has given Sistelec a strong reference to extend its specialization in wireless networks for smart cities and it has been a good opportunity to exchange know how with partners like Telecom.
· LEYCOLAN: The implementations carried out within the REPLICATE project have given Leycolan the opportunity to showcase their experience to other municipalities, especially with Silfi the third party working in Florence, and consolidate its knowledge in Smart Public Lighting.
· MATHEMA: Mathema is consolidating its knowledge in Smart city platforms connections, data management and APP development (UNIFI, Eurohelp and Toshiba) and it is gathering experience in innovative infrastructures for e-mobility thanks to the collaboration with e-distribuzione.
· CO-WHEELS: Co-Wheels are currently testing e-bikes that are deployed within health and community organisations working in the project area. Pre-Replicate they offered a few hybrid cars, however this project will enable both fully electric powered cars and bikes in the project area. The exchange of knowledge with Florence for charging stations and sharing systems has enriched their background.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

ANNEX 1: Overview of the lighthouses' pilot measures and partners list

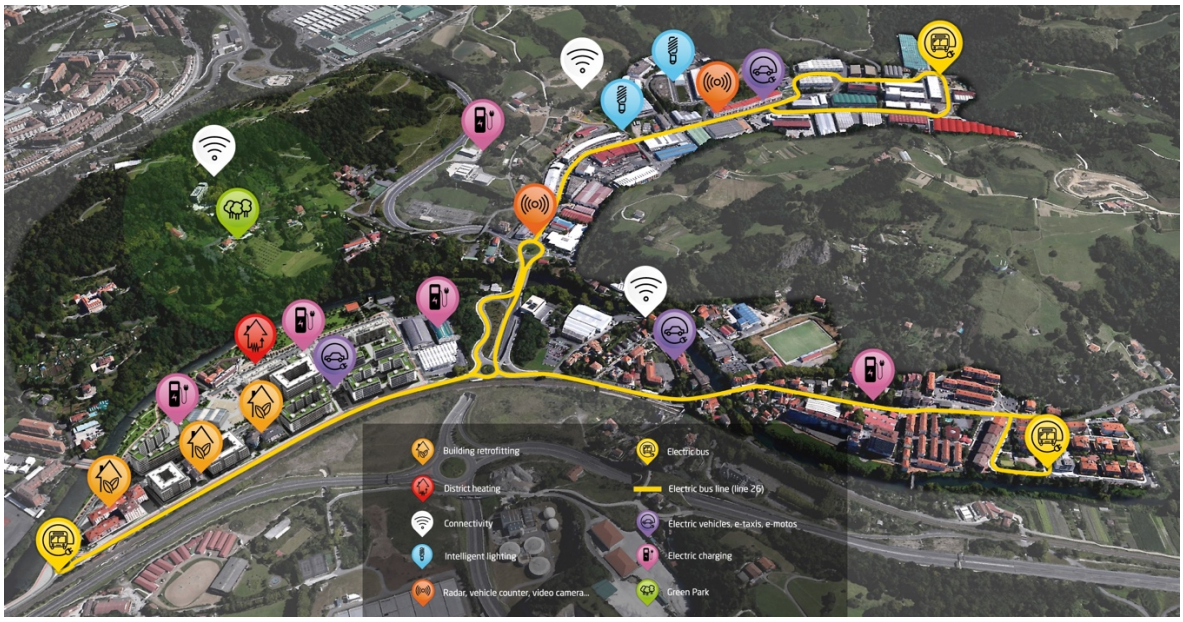
Sommario

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

1. San Sebastian pilot

1.1 Overview of the main measures:

URUMEA RIVERSIDE DISTRICT



The city has an integrated strategy aiming for a smart district. With the particular objective of getting a nearly zero district: district branding in sustainability.

San Sebastian wants to enhance the transition process to a smart city in 3 areas: Energy Efficiency, Sustainable Mobility and ICT / Infrastructures.

Energy Efficiency

- Building Retrofitting in 156 dwellings and 34 commercial premises, distributed along 10 doorways.

- District heating system to give service to more than 1.500 new properties and 156 existing dwellings. With a power plant with 7400 kW of power, with two 1400 kW biomass boilers. It will have the following environmental benefits: reduction of 35% in primary energy consumption, being over 90% of this energy renewable. CO2 emissions reduced by 85%.

The service is owned by Fomento de San Sebastián.

- A Demand Side Platform for the monitoring of residents' consumption fostering sustainable behaviour.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

Sustainable Mobility

- Electric buses have been deployed: 2 full electric + 2 hybrid buses for line 26 to link the district with the city centre.
- Public EV 4 e-cars and 6 e-motos for municipal fleet.
- Private EV: 7 e-taxi
- Charging infrastructure deployment in the city:
- Mobility Smart City Platform and advanced mobility services development.

ICT and Infrastructures

- Smart City platform deployment with integrated services.
- Open Data and Citizen Participation services.
- IP services deployment in Poligono 27 and high-speed connectivity network deployment for the whole city.
- Smart Lighting deployment in Poligono 27.

1.2 Partners list:

Fomento San Sebastian (project coordinator): Fomento San Sebastián S.A is a public municipal company dedicated to the promotion and the economic and social development of the city through innovation, the generation and transformation of knowledge, networking, and the promotion and management of projects, all in accordance with criteria of sustainability.

Fomento de San Sebastián, has also designed a Smart Plan for the city with an Action Plan for 2016-2020, in which an integral plan for the city's smart strategy is established with the main challenge of establishing a strategic line with shared objectives and to give coherence and coordination to the public action. Fomento San Sebastián is in charge of the coordination of the Replicate project, leading and coordinating all the actions of the project and ensuring a proper execution. In particular, in the pilot of San Sebastian, it is in charge of the coordination of the actions deployed in the city and it is also the leader of the energy implementations. FSS has been developing a municipality WiFi service since 2004 to provide electronic communications services. Fomento San Sebastian is also the responsible for the deployment of the public fibre optic network of the city.

Within the REPLICATE project, Fomento San Sebastian is the owner of the District Heating and is in charge of continuing the implementation of the broadband wireless network to other areas without coverage and to enhance the actual post WiMAX deployment.

San Sebastian City Council (project partner): The municipality of San Sebastian is in charge of the implementations in the pilot of San Sebastian together with Fomento San Sebastian, who acts as the coordinator and manager of all the actions carried out in the city. Several departments of the city

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

council take part in the project (leaded by Fomento de San Sebastian): Mobility department, Town Planning department, Infrastructures and Urban Services department, Etxegintza (Housing department), Environment Department, Public Lighting department and Citizen Participation department.

DonostiaTIK- Municipal Computer Center company (third party): DonostiaTIK is the City Computer Center company belonging to the City Council of San Sebastian. DonostiaTIK is in charge of the coordination of the ICT and Infrastructures implementations and has deployed the Smart City Platform. They will do all the works related with the maintenance, integration and hosting of the common platform within the city with the local computers and data from San Sebastian city.

EUROHELP (partner): With a team of more than 200 professionals with extensive experience and high technical qualification, Eurohelp is an IT consulting firm that offers innovative solutions to private companies and the Public Administration. In San Sebastian Pilot, data gathered from Mobility, Energy Efficiency and ICT solutions are to be published in Linked Data formats (RDF), being Eurohelp responsible for both the data processing and transformation, Besides, Eurohelp is developing a Citizen Participation platform to assist municipality managers in decision-making processes. EUSKALTEL (project partner): Euskaltel is a Telecommunications Operator and CATV Operator (CableCo) in Basque Country established in 1995. It is Independent Mobile Operator operating its own network also for Mobile services. In order to do that, Euskaltel has adopted the Full Mobile Virtual Network Operator (MVNO) model, with its own CORE network. It is in charge of providing aggregated data about the mobility of people.

Giroa-Veolia (project partner): Giroa-Veolia is the specialist of energy and environment management services company of Veolia also dedicated to the maintenance, conservation and adaptation of buildings, installations and complexes of different nature, in order to improve their comfort, performance and security. Giroa-Veolia, company with more than 35 years of experience in the market, where it has been a forerunner in the Saving Share and in the Guarantee of Results, (ESCO Company) has created a new conception of job and service, based on a pragmatic approach to the demands of its clients. Giroa-Veolia is the partner in charge of the retrofitting intervention.

IKUSI (project partner): Ikusi is a global leader in the design, implementation and management of electronic systems with a large presence in the Spanish and international markets. IKUSI provides mobility solutions for the management and regulation of public transport, traffic management, road safety, charging for use, integrated fare management and security solutions infrastructure, citizen information systems and value-added services. Within the project framework, Ikusi is in charge of the deployment of the Smart Mobility Platform.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

LEYCOLAN (Project partner): Leycolan S.A.L. was founded in 2015 as an engineering company, focused on providing high energy savings in street light infrastructures and converting the existing power grid into IP networks. The team comprises of highly qualified engineers, experts in Broadband PLC communication systems, and experts in lighting technology.

Leycolan takes part in San Sebastian Pilot, deploying and implementing the replacement of the street lights into new LED lights and the implementation of a new intelligent system and the remote-control system on an online operation basis.

SISTELEC (project partner): Sistelec is a wholesaler specialised in wireless communications who is in charge of Installation and deployment of high-speed mobile network based on postWIMAX technology. Sistelec has created the transport layer which will increase coverage areas and will include more robust wireless security protocols of the time. The transportation network develops relevant applications to manage all the services received by the high-speed mobile network.

TECNALIA (project partner): Tecnalia is a private, independent, non-profit applied research centre of international excellence. Legally a Foundation, Tecnalia is the leading private research and technology organisation in Spain and one of the largest in Europe employing almost 1.400 people.

In Replicate Tecnalia is the technical coordinator of the project and it is also leading the monitoring and the definition of common developments for the Smart City platforms that are under development in each city. In addition to these transversal tasks Tecnalia is also developing specific interventions at pilot level in San Sebastian:

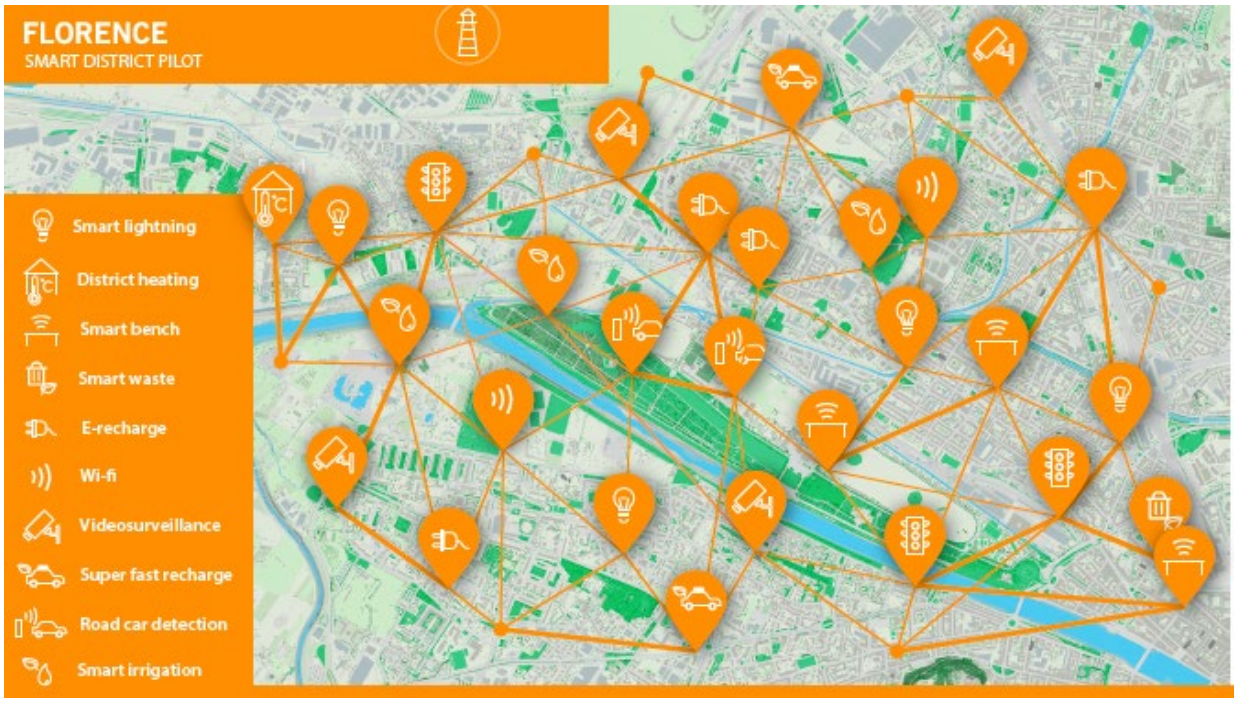
- contributing to the mobility service by developing all the analytical work, including algorithms, for the preparation of origin/destiny matrixes out of big data generated from mobile telephone company.
- Implementing and preparing the Energy Demand System to provide with information to consumers letting them to save by learning more efficient ways. The system will also help to operate the District Heating in a more optimal way so that there can also be energy savings not only for the company but also for consumers.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

2. Florence pilot

2.1 Overview of the measures:

NOVOLI / CASCINE / LE PIAGGE



The pilot area: Cascine/Novoli/Le Piagge

An integrated strategy aiming at implementing the Smart City Plan in a smart district to be replicated and scaled up at metropolitan level. The area has been selected because it is hosting a mix of uses (industrial settlements dismissed and tertiary activities) including a big residential settlement (5000 m² constructed area/6000 buildings), the presence of the biggest park of the city and the relevance for the mobility sector (city's entrance, airport, stations, highway, tramlines under construction, bike paths,…).

ENERGY

- ✓ Retrofitting and district heating: social housing, 300 dwellings with 700 people, 20.000 m². The main objective of the intervention is the exemplar transformation of two residential buildings, tackling energy poverty, implementing shell insulation and the disposal of old existing individual heating systems with a high-performance micro DHS producing energy with high RES exploitation through an innovative solar thermal seasonal storage. Target: saving consumption 50% and energy bills for tenants 10%.
- ✓ Smart grid: functionalities on L/MV network on 2 primary and 60 secondary substations The aim is to create a resilient network system by reducing outages and increasing the quality of service

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

together with the resilience of the grid, enabling advanced functionalities and new value added services for the citizens and the PA Target: 25.000 citizens involved, - 3100 t CO_2 /year.

- ✓ Smart info: device to monitor real time electricity consumption. Residential apartments/families in the pilot area of Florence will be equipped with Smart Info, to increase customer awareness providing user-friendly info. A supporting app, including heating consumption and mobility behaviours, with gaming to reward the energy heroes is foreseen. Target: 600 families involved

MOBILITY

- ✓ e-mobility: promote the EV The aim is to improve the public recharging network in the pilot area and make the taxi service more efficient (full electric taxi vehicles and very fast recharge) to decrease the impact of mobility and to promote e-vehicles also in the private sector; facilitations for taxi owners are already in place (reserved fast recharging stations, app to book the recharge and see real time info about the public stations, agreements with vehicles providers for special conditions, reduced license fees, prioritization of the e-service). Target: 100 e-taxi, 6 very fast recharge for taxi drivers, recharging public stations, - 250 t CO2 /year
- ✓ advanced mobility service: new services to enhance sustainable mobility and to reduce traffic. The aim is to offer a comprehensive information system to control mobility for the PA, advanced mobility services to citizens, an ad hoc system for taxi fleets. Target: improve and promote sustainable public mobility

ICT & INFRASTRUCTURE

- ✓ Smart lighting: refurbishing with led lights and empowering adding services the public lighting infrastructure. The action consists in the furniture of led bulbs with technical equipment for value-added services (refurbishment of the network), luminance digital sensors, self-diagnostics and maintenance management in order to reduce the emissions and light pollution and enable the deployment of a smart light system (with sensors, WiFi, light video surveillance on board). Target: 1000 led lights, value-added services, - 3500 t CO2 /year
- ✓ ICT: city-wide dashboard regarding Smart City measurements. The aim is to achieve a responsive smart city platform (Florence control room) to manage the city in real time, enabling the remote control by the city decision-makers, and to improve the digital basket for citizens with new apps and open data. Data management, big data and open data, local services management and digital services are at the basis of the development of the structure. Target: comprehensive Smart City Platform, wide digital basket for citizens in use from 2019.
- ✓ IOT and capillary network: smart IoT devices and the supporting infrastructure tested in urban environment. The aim is to develop a sensible city able to make use of smart and intelligent technologies: smart irrigations, smart benches, smart waste and TiM CityLink are the first internet of things applications tested in the pilot area. Target: to develop three new IoT services and the related capillary network able to interface with the city platform

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

2.2 Partners list:

Municipality of Florence (project partner):

The Municipality of Florence is the lead partner for the Florence pilot and is responsible for project management and coordination. The city is the owner of the Public Lighting network and service as of the Public e-vehicles charging network and service and it is the regulatory body for public mobility.

Casa spa (Third party), the social housing company of Florence and its neighbour municipalities, is the building manager and also an ESCo.; they have been in charge of the insulation and storage design.

CNR (project partner): The National Research Council (CNR) is the largest public research institution in Italy. CNR's mission is to perform research in its own Institutes, to promote innovation and competitiveness of the national industrial system, to promote the internationalization of the national research system, to provide technologies and solutions to emerging public and private needs, to advice Government and other public bodies, and to contribute to the qualification of human resources. CNR is involved in the Florence pilot, where it participates in activities on electrical mobility and energy efficient buildings for the Florence pilot. It also participates in cross-cutting activities, on the activities related to evaluating the effectiveness of energy efficiency actions. CNR has developed an external *Web Service* that can be accessed by the Energy APP through standardised APIs to construct the *Energy Profile* of dwellings by using very limited qualitative data.

e-distribuzione (project partner): e-distribuzione is a Distribution System Operator (DSO) and a subsidiary of the Enel Group, Italy's largest power company and Europe's second listed utility by installed capacity. With about 32 million consumers and more than 1,100,000 km lines, e-distribuzione is the second largest DSO in Europe. As well as providing power distribution services to its household and business consumers, the company runs R&D activities with the aim to constantly improve supply services to consumers and facilitate new advanced services to the customers in the framework of smart grids developments. Solutions for the integration of renewable energy sources as well as the active participation of customers in the management of the electricity network have been investigated and tested by the company under different national and European projects. E-distribuzione in REPLICATE is involved in the implementation of the Florence's pilot and it is responsible for the pilot's following activities: smart grids; energy demand management (i.e. Smart info), EV fast recharging infrastructures installation and management.

Enel X (project partner): Enel X is part of Enel group and entered the project to develop the public recharging network and its management system in connection with the city platform.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

Mathema (project partner): Mathema is a R&D performing ICT company active since 1987 whose main mission is to support very large public and private organisations in the development of world-wide cloud based complex information systems, in the analysis and mining of large data sets, in the development of smart mobile apps. In particular the core activities and competencies span from Very Large database (VLDB) management, Crowd sensed information, Ontology based Data Fusion and Mining, Social Intelligence, Big Data/Open Data analytics, Augmented reality, and Service Gamification.

The specific contribution in this action refers to the app to manage the fast recharging network for taxi drivers (localization, availability, reservation of the stations)

SILFI (third party):

SILFI is an in-house (totally public owned) company of the Municipality of Florence and it is in charge of the public lighting system, the traffic lights and all the smart services of the city including info-mobility

It is enrolled as ESCO at national level and it works also on the Smart City Control Room action.

SPES Consulting (project partner): SPES is a SME born with the aim to offer interdisciplinary consultancy services in the field of sustainability and innovation. In Replicate SPES, above the technical support to the municipality of Florence in its pilot, aims to support cross cutting activities among lighthouses and to develop replication plans. SPES main tasks on behalf of Florence are:

- evaluate the compatibility of the realisation of the project's objectives.
- support the selection of the technologies and solutions evaluating replicability potential and impacts.
- support the local consortium management.
- support the updating of the planning framework and stakeholders' involvement.
- support in the management models definition.
- monitoring and EMS implementation.

Moreover, SPES, in close contact with the lighthouses and the other project leaders, will:

- promote the experience exchange among international partners.
- assess the technologies, approaches and business plans of the various measures adopted in the lighthouses.
- develop, together with the lighthouses, replication plans.

Telecom (project partner): The Telecom Italia Group is a major Italian enterprise and a key European strategic ICT player. Driven by technological innovation and a commitment to service excellence, Group companies operate in fixed-line and mobile telecommunications, Internet & Media, Information Technologies. Most of the R&D activities of the Group are performed inside the Innovation Department. The work carried out by the Innovation Department is the outcome of a

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

strategic partnership with the main manufacturers of telecommunications equipment and systems, and with centres of excellence in research at the most highly qualified national and international academic institutions. Telecom Italia in REPLICATE has to provide the IoT Connectivity Platform currently at standard ETSI M2M and specifications for the following smart city services: smart waste, smart bench and smart green.

Thales (project partner):

Thales Italia spa (THALIT) is the Italian branch of the French Group Thales and it provides technological solutions designed for several markets (Civil security, mobility and terrestrial transports, air navigation systems, protection and surveillance of critical infrastructures, airports, defence, etc.). Thales Italia is strongly oriented to innovation and to keep many and useful cooperation agreements with highly qualified universities and Research Centres in Italy, in addition to cooperation with international research centres trough structures and agreements organized at Thales Group level, worldwide.

Thales collaborates with the Municipality of Florence (Comune di Firenze) to implement the pilot by supporting the design of ICT solutions, video supervision, system integration aspects and the deployment of Smart City Control Room.

UNIFI (project partner):

The University of Florence is acting on the project with two departments: DINFO, Department of Information Engineering with its DISIT lab and research group, providing an infrastructure for cloud and distributed computing, and DIEF, Department of Industrial Engineering, involved with a research group that is historically based on the field of energy systems. DINFO is actively involved in the Florence pilot for Local IT Systems integrated with ICT Smart City Platform concept and ontology, Data Management, digital services development.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

3. Bristol pilot

3.1 Overview of the measures:

ASHLEY, EASTON & LAWRENCE HILL SMART DISTRICT

Bristol City Council is the lead partner for the Bristol pilot and is responsible for project management and coordination

Bristol will deploy a number of smart **integrated energy**, **mobility** and **ICT solutions** in the neighbourhoods of Ashley, Easton and Lawrence Hill. The Bristol pilot will explore how technology could help tackle inequalities, such as how smart homes could help ease fuel poverty, and how electric bikes could help people to be more active and have more choice in how to travel.

REPLICATE offers an opportunity for people in Bristol to test "tomorrow's technology today", learning about and becoming familiar with new technologies that will become increasingly commonplace. The project will contribute towards Bristol's ambition to be carbon neutral and run entirely on clean energy by 2050.

Led by Bristol City Council, and partners, the Bristol pilot aims to explore how smart technology could be used to:

- Reduce the cost and amount of energy consumed to help tackle **fuel poverty**.
- Use more local clean **renewable** sources of energy to increase local **resilience**.
- Enable greater sustainable mobility to increase **health and wellbeing** as well as enable better access to **training and employment**.
- Engage citizens in their **energy use** and **travel patterns** to enable them to make the changes they want to.
- Contribute to an overall aim to help significantly **reduce the city's CO_2 emissions.**

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

Bristol's pilot has three strands through which citizens can get involved:

1 **Smart homes** – trialing connected appliances, installing energy efficiency measures and exploring renewable energy generation through a district heating network.
2 **Smart streets** – exploring electric and shared-use vehicles including a shared e-taxi, e-bikes and a car club, as well as new ways of getting around, supported by a parking app and a regional multimodal travel advice website and app.
3 **Created by us** – working with local people to explore new ways of tackling local problems with technology such as sensors and understanding how data can be used.

Smart city elements that will be deployed in Bristol include:

- Development of an Energy Demand Management System.
- Energy efficient retrofitting of 240 homes, including 150 "Smart Homes" (trialing smart appliances).
- Development of local renewable energies (district heating, community solar PV).
- Electric vehicles and charging infrastructure (including e-bikes, electric car club vehicles, an on-demand shared electric taxi service and electric vehicle charging points in the district).
- Multimodal travel planning and parking apps.
- Development of a smart city ICT platform.

3.2 Partners list:

Bristol City Council (project partner): Bristol City Council is the lead partner for the Bristol pilot and is responsible for project management and coordination. It also leads on the Smart Homes and manages the retrofit and district heating interventions.

Bristol will deploy a number of smart integrated energy, mobility and ICT solutions in the neighbourhoods of Ashley, Easton and Lawrence Hill. The Bristol pilot will explore how technology could help tackle inequalities. REPLICATE offers an opportunity for people in Bristol to test "tomorrow's technology today", learning about and becoming familiar with new technologies that will become increasingly commonplace. The project will contribute towards Bristol's ambition to be carbon neutral and run entirely on clean energy by 2050.

Bristol is Open – BiO (project partner): Bristol Is Open (BIO) is a joint venture between the University of Bristol and Bristol City Council. It was initially funded by the local, national and European governments. BIO is an R&D test bed for experimentation around connectivity and IoT and Smart City solutions at a city scale. Bristol Is Open (BiO) is involved in the Bristol Pilot and is responsible for helping the project's technology to connect through the smart city platform and work together.

Bristol is Open are involved in different tasks of the REPLICATE project such as:

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

The integration of the demonstration IT systems with ICT Smart City Platform. During this task, the demonstrated IT systems in Bristol will be integrated with the ICT Smart City Platform in a controlled environment. This will involve a large number of actions, such as:

- Network/computing resources; through optical fibre links (the core) and wireless connections (access points/network).
- Sensors and actuators through wireless solutions provided on the platform.
- Defining the interfaces for enabling existing or enhancing customer premises IoT connectivity.
- Active input into the creation of a set of software defined networking tools, development of the core Network Operating System (NetOS™) for network control and virtualization, prototype future demonstration (by UoB and Zeetta) of the Smart City Platform (FIWARE and NetOS) and integration with different ICT services.

They will also work together with other project partners to (for example):

- Feed requirements to inform creation of different sets of tools for the Software Defined Control.
- Enable Integration of the NetOS with a demonstrator FIWARE platform using well-defined FIWARE standards.
- Investigate different approaches for the integration of FIWARE in physical or virtual infrastructures.
- Capturing requirements and developing solutions or making changes to BIO to enable connections into BIO.
- Provide a capability to capture and host experimental data for agreed project partners.

Co-wheels (project partner): Co-wheels is the only independently-owned national car club, providing low emission, hybrid and electric cars on a pay-as-you-go basis for organisations and communities across the UK. Co-wheels now deliver car clubs in over 60 locations across the UK. They have a diverse range of operations, from city centres to villages. Some of their cars are used by local authorities and universities as pool cars for staff, whilst others focus entirely on being shared cars for local residents.

Co-wheels are involved in the Bristol Pilot and are responsible for deploying e-bikes and EV cars in a car club.

EV car club: electric cars – Renault Zoes – which have been deployed in the Ashley, Easton and Lawrence Hill area as part of the Co-wheels car club and accessible to the public, tourists and businesses / organisations.

E-bikes: e-bikes have been deployed in the Ashley, Easton and Lawrence Hill area as part of the Co-wheels car club; primarily designed to be available for voluntary healthcare sector organisations to facilitate journeys made during the working day, it is envisaged that this could evolve to become a

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

public facing bike share scheme. The bikes are power assisted which means it will make it easier for people who may not usually cycle to get involved.

Knowle West Media Centre (project partner): KWMC supports people to make positive changes in their lives and communities, using technology and the arts to come up with creative solutions to problems and explore innovative ways of doing things. The arts organisation and charity has been based in South Bristol since 1996 and offers skills training and employment for young people, an award-winning digital manufacturing space, and a diverse programme of creative projects exploring issues from energy to health.

KWMC is involved in the Bristol Pilot and are responsible for supporting Bristol partners to work with community organisations, volunteers and local residents within the REPLICATE Bristol pilot areas.

KWMC is also leading the activities of Bristol's 'Created by us' work strand, which will use their methodology 'The Bristol Approach to Citizen Sensing' to support residents to use appropriate digital technologies to tackle other issues within their area, such as damp homes and air quality.

Other partners involved in The Bristol Approach include universities and Ideas for Change; the University of Bristol and University of the West of England are assisting by contributing their experiences in the public understanding of science and through providing independent evaluation of the engagement process.

NEC (project partner): NEC Laboratories Europe focuses on software-oriented research and development of technologies to enable advanced solutions for society. In particular, innovative communication architectures and systems are developed that apply the software defined network paradigm to next generation fixed and mobile networks. Strong security technologies that provide data privacy and dependability are indispensable ingredients of future ICT solutions. Data acquisition and analytics technologies enable innovative solutions in the areas of smart transport, smart energy and sensor-enabled smart world solutions.

NEC is involved in the Bristol Pilot and is in charge of the Energy Management System – Holistic monitoring and analysis of demand and supply. This task will provide a management system for monitoring for consumers and producers, as well as control of the energy demand for selected use cases. This will include all energy resources made available in the Bristol pilot, e.g. the households smart whitegoods or the electric storage, electric vehicles' charging needs, intelligent lighting of districts, and the PV installed (monitoring energy production only) on public and community buildings (if any) during the project. The core work is focussing on the development of energy balancing algorithms to enable a demand-side-management (DSM) participation trial.

Integrating the control logic, the Bristol Pilot community power cluster's energy management is implemented and deployed for different business models. It will be evaluated for potential integration into the smart city operation centre or energy control room solutions, enabling customer assurance and satisfaction.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

Route Monkey (project partner): Route Monkey is one of the UK's leading players in the optimisation of assets including vehicles, goods, people and energy. Its powerful algorithms can help organisations to cut costs and emissions, while improving productivity.

Route Monkey is a specialist developer of algorithms and is involved in the Bristol Pilot. It is responsible for adding functionality to the TravelWest journey planner. REPLICATE will provide flexible transport options and air quality improvements through integrated use of electric vehicles and electric bikes. Route Monkey will be supporting the project through enhancements to the Travel West journey planning app to help residents make best use of both traditional and new multi-modal mobility options within the city.

Toshiba (TRL) (project partner): Since its inception in 1998, the Telecommunications Research Laboratory (TRL) has been at the cutting edge of research into technologies including next generation wireless networking, reconfigurable device architectures and 'smart' systems for energy, mobile and medical applications. TRL works closely with colleagues in Toshiba's development laboratories around the world to ensure a timely transfer of technology from research towards standardisation and into products. Toshiba is involved in the Bristol Pilot and is responsible for developing ParkUs, a parking app to reduce congestion and cruising time when looking for a parking space. The App will include a 'heat map' style display of the on street parking available in the pilot area.

University of Bristol – UoB (project partner): UoB is a leading research-intensive UK university, which was ranked among the top 50 universities in the world in the QS World University rankings 2016.

As part of the Bristol Pilot, the various University of Bristol teams (UoB-HPN, UoB-ITS, UoB-EFS), are mainly in charge of the development of digital technology and the deployment of sensors, e.g. air quality monitors and e-bike trackers (HPN, ITS), as well as contributing to citizen engagement research (EFS). UoB HPN and ITS had an integral part in the ICT systems demonstration and the ICT Smart City Platform (SCP) development (HPN) based on the FIWARE framework. They are also involved in the development of the demand side response trial with REPLICATE's smart homes. Citizen engagement tasks included researching community engagement and citizen perceptions (EFS). The ICT tasks involve a large number of actions that range from the deployment of the infrastructure to the demonstration/integration of the SCP with different ICT services and use-cases, such as citizen-led air quality monitoring. UoB-HPN worked on different approaches regarding the integration of the BiO Infrastructure and FIWARE. In particular, this consisted of:

- FIWARE installation in the physical network;
- FIWARE on a network slice; and
- FIWARE distributed over several slices.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

University of West England – UWE (project partner): UWE Bristol is a University Alliance university with a common mission to make the difference to cities and regions. They use their experience of providing high quality teaching and research with real world impact to shape higher education and research policy for the benefit of students, business and civic partners. They innovate together, learn from each other and support every member to transform lives and deliver growth.

UWE is contributing the Bristol Pilot, within which it is undertaking planning, coordinating and analysis tasks towards effective monitoring and evaluation of the implementations. UWE Bristol is also contributing to the cross-cutting analyses to support scale-up and replication.

UWE is preparing evaluation plans for each demonstration considering both quantitative indicators as well as qualitative information necessary to understand the effects of the implementations. The demonstrations include energy and mobility initiatives as well as ICT applications in the mobility sector. Once established, each plan will be followed with the collection of data, back-end recording systems, and specific investigations (surveys of users, interviews with stakeholders). In addition, UWE will assist in the analysis of the city experiences with a view to assessing their practicality and cost-effectiveness for replication elsewhere, as well as the development of a business-model road map for delivery.

Zeetta (project partner): Zeetta Networks transforms your network into an interactive programmable platform for better control, improved efficiency, enhanced performance and better cost controls of your existing infrastructure. Zeetta's vision is to allow enterprises, cities and network operators to scale up the capabilities of their network and satisfy the demand for data without escalating CAPEX and OPEX costs. Put simply, to make the most out of their network capability through use of our NetOS® software. Zeetta, part of the Bristol Pilot, is involved in developing ICT Smart City Platform and integrating REPLICATE ICT Systems.

Zeetta Networks will be working on ICT and infrastructure actions with some partners to:

- Integrate the demonstration IT systems with the ICT Smart City Platform concept.
- Creation of a set of software defined networking tools.
- Development of the core Network Operating System (NetOS™) for network control and virtualization. Understand the Network Operating System (NetOS) as a component for the Smart City Platform. It could provide different network slices for different users and purposes on demand (granting Infrastructure as a Service (IaaS)).
- Integration of the Network Operating System and FIWARE.
- Prototype demonstration of the Smart City Platform (FIWARE and NetOS) and integration with different ICT services.

ZEETTA will also actively input into the following actions:

- Different approaches regarding the integration of BIO Infrastructure and FIWARE.
- Contribute to the prototype demonstration of the Smart City Platform (FIWARE and NetOS)
- ICT services and their integration with the Smart City Platform.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

ANNEX 2 The methodology adopted

Sommario

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

1. The methodology adopted

Many partners have been involved in the methodology definition: starting from the lighthouses (the main user addressed), feedbacks have been asked to technical partners (Tecnalia, University of West England) and interested WP leaders (ESADE, universities of Oxford and Exeter) and the three followers. The information exchange is based on the City Data Canvas developed in D7.1, while the actions have been assessed following the methodology developed in WP10 regarding the replication KPIs described in the following paragraphs.

1.1 The City Data Canvas from D7.1

In D7.1 ("Peer review methodology") a template for describing the common actions in the three City's pilots has been developed: its aim was to harmonize the information and to have a unique reference for the pilot analysis. There are not many comprehensive methodologies for analysing a smart city's integrated action from different points of view (technical, environmental, financial, social,). Addressing this need, the proposed framework identifies the key elements of each smart services, their interaction and the overall effect of the integrated implementation. This tool, named the City data Canvas, inheriting the name form the economic sector models, can be used by lighthouses to describe their actions and the context.

In accordance with WP10 – Monitoring, it has been decided to consider two different levels of analysis: City level (first table of the template) and intervention level (following tables); in the interventions tables, some standard elements have been suggested but cities were free to add tabs and to provide also files in annex to illustrate relevant aspects.

After a first review of the cross-cutting actions which make the pilots, a common core set of interventions has been agreed with the lighthouses as illustrated in the picture below.

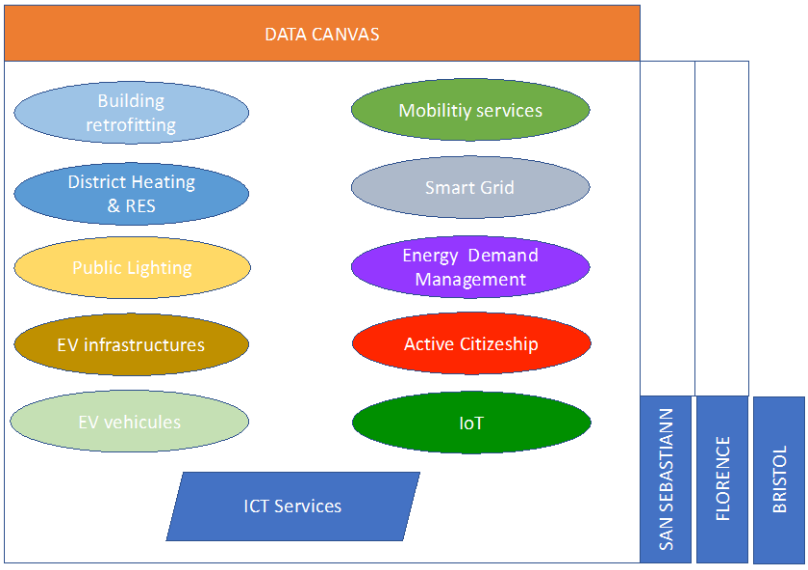


Figure 1 – Common topics suggested for the pilots' description

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

In each table different kind of information have been asked to analyse the action from different points of view. The main sections included in the template are summarized in the following scheme.

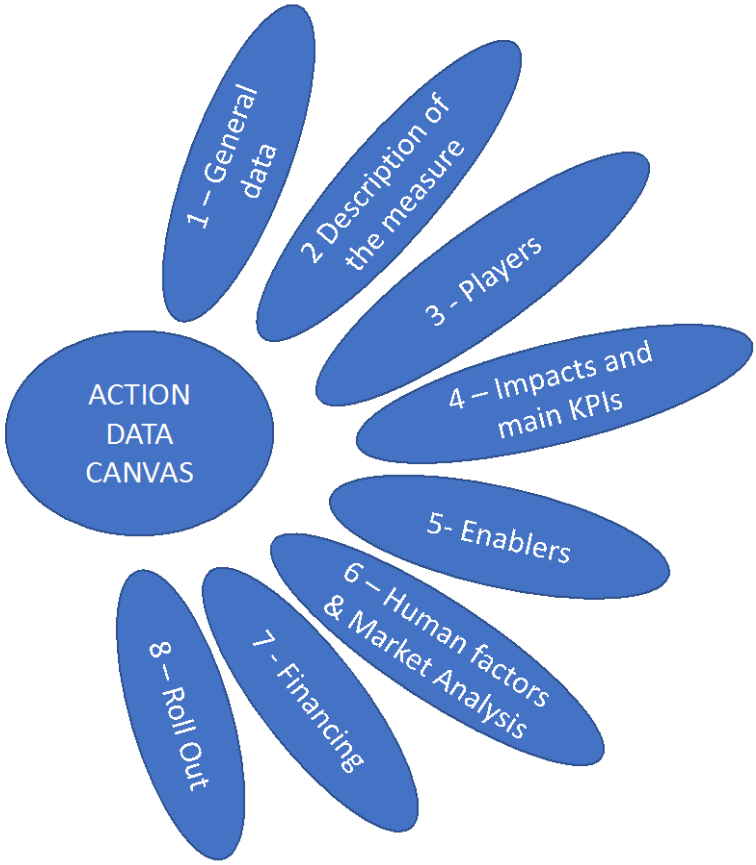


Figure 2 – Data composition for each measure

In the present document the sections of the City Data Canvas much related to the technical implementation have been detailed and analysed. The content includes:

- Description of the action: general description of the key activities (what and who)
- Value proposition: Core value and main issues to be targeted (why)
- Technology: The solution in use and their innovation level (how)
- Main impacts of the measure (economical, environmental, social) both direct and indirect
- Market analysis: enablers and obstacles (Competitors, legal framework & incentives, human factor)
- First scale up analysis: Lessons learnt, Optimal scale for next implementations, Further developments needed, Expected impacts.

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

1.2 The replication KPIs

To analyse the replication/scalability potential, together with WP10 has been decided to implement the Citykeys indicators for Smart City Projects.

This set is available only on the project level, because the data for most indicators will have to come from the project documentation and/or interviews with the project leader and others involved in the project. In the Propagation theme, also the overall impression of the project on the assessor will play a role, for example with regard to the likelihood that the project will be replicated or scaled up in other areas or with other stakeholders. Due to the nature of the theme, most indicators in this theme are semi-quantitative outcome or impact indicators; all are assessed by Likert scale. Most indicators only need scoring after the project and can also be used ex-ante to evaluate the quality of plans. The indicators are relevant for any type of project.

The replication and scalability KPIs, developed together with the partners in charge and the respective lighthouse, have been used to draw radar charts supporting the evaluation and the comparison.

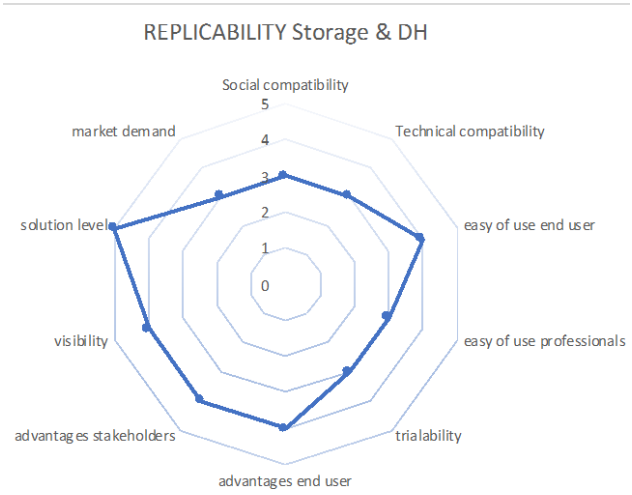


Figure 7.10 example of radar chart developed with Replicability and scalability KPIs

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

4. CITYKEYS INDICATORS FOR SMART CITY PROJECTS			
4.6 Propagation			
4.6.1 Replicability & scalability			
Indicator title	**Unit**	**Definition**	**Source**
Social compatibility	Likert scale	The extent to which the project's solution fits with people's 'frame of mind' and does not negatively challenge people's values or the ways we are used to do things.	Eurbanlab
Technical compatibility	Likert scale	The extent to which the smart city solution fits with the current existing technological standards/infrastructures	Eurbanlab
Ease of use for end users of the solution	Likert scale	The extent to which the solution is perceived as difficult to understand and use for potential end-users	Eurbanlab
Ease of use for professional stakeholders	Likert scale	The extent to which the innovation is perceived as difficult to understand, implement and use for professional users of the solution	Eurbanlab
Trialability	Likert scale	The extent to which the solution can be experimented with on a limited basis in the local context before full implementation	Eurbanlab
Advantages for end users	Likert scale	The extent to which the project offers clear advantages for end users	Eurbanlab; 2DECIDE; CIVITAS; ISO 37151;
Advantages for stakeholders	Likert scale	The extent to which the project offers clear advantages for stakeholders	Eurbanlab
Visibility of Results	Likert scale	The extent to which the results of the project are visible to external actors	Eurbanlab
Solution(s) to development issues	Likert scale	The extent to which the project offers a solution to problems which are common to European cities	Eurbanlab
Market demand	Likert scale	The extent to which there is a general market demand for the solution	Eurbanlab

This Project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement N° 691735

4.6.2 Factors of success			
Indicator title	**Unit**	**Definition**	**Source**
Changing professional norms	Likert scale	The extent to which the project changes the professional 'state of the art'	Eurbanlab
Changing societal norms	Likert scale	The extent to which the project changes the norms and values of the society	Eurbanlab
Diffusion to other locations	Likert scale	The extent to which the project is copied in other cities and regions	Eurbanlab
Diffusion to other actors	Likert scale	The extent to which the project is copied by other commercial parties	Eurbanlab
Change in rules and regulations	Likert scale	The extent to which the project has contributed to, or inspired, changes in rules and regulations	Eurbanlab
Change in public procurement	Likert scale	The extent to which the project has contributed to, or inspired, new forms of public procurement procedures	Eurbanlab
New forms of financing	Likert scale	The extent to which the project has contributed to, or inspired, the development of new forms of financing	Eurbanlab
Smart city project visitors	#	The number of visitors to the physical project site or to the website hosting the smart city project	

For a detailed description of each KPI and the guide for the assessment please refer to CityKeys D1.4 "Smart city KPIs and related methodology – final" at http://www.citykeys-project.eu/citykeys/cities_and_regions/Project-Deliverables