C.2.2 Large scale in-field test pilot report

DIADEME LIFE15 CCM/IT/000110
TEST REPORT
PIACENZA SITE
25/08/2020 – 31/12/2020

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Contents

DOCUMENT PURPOSE

This document explains the results of the energy savings lighting test performed in Piacenza and Via Primo Maggio, from Tuesday, 25 August 2020 to Thursday, 31 December 2020.

LIFE-DIADEME PIACENZA OVERVIEW

LIFE-DIADEME aims at demonstrating a novel and cost-efficient Distributed Adaptive Lighting dimming system. The system will overcome the limitations of the state-of-the-art pre-regulated street lighting solutions and significantly reduce (30% as project target) street lighting energy consumption and CO_2 emissions. Al the activities comply with the UNI 11248 standard on Adaptive Lighting, further enhancing benefits brought by SSL (Solid State Lighting) systems and traditional lighting lamps.
This novel system will integrate state-of-the-art low-cost sensors based on a distributed network, allowing the extension of helpful data detection and monitoring (i.e. noise, traffic and air pollution) to entire cities roads.
Rome (EUR and Pietralata district), Rimini and Piacenza municipalities collaborate with the consortium allowing systems installation along city streets.
Citelum installed the Piacenza test site during July 2020.
The consortium switched on the Adaptive lighting method on Tuesday, 25 August 2020.
At this time, the adaptive lighting in Piacenza it's still working.
About the luminance level road category, the selected road is an M3.
For this kind of street are applied the following nominal parameters.

- Nominal Luminance Level: 1 cd/m^2
- Maximum Road Traffic: 800 vehicles/hour
- UNI11248 Full Adaptive Lighting – Minimum Luminance Level: 0.3 cd/m^2

Figure 1 visually exposes different luminance levels depending on the street lighting strategy for an M3 road. In red, the Full Light strategy where the road traffic doesn't affect the luminance levels.
In blu, the street luminance levels allowed by a pre-programmed statistical system.
In green, the adaptive lighting luminance levels permitted by technical directive UNI11248.
Real-time traffic evaluation enables lower luminance levels and linear regulation between the maximum and minimum level of light.

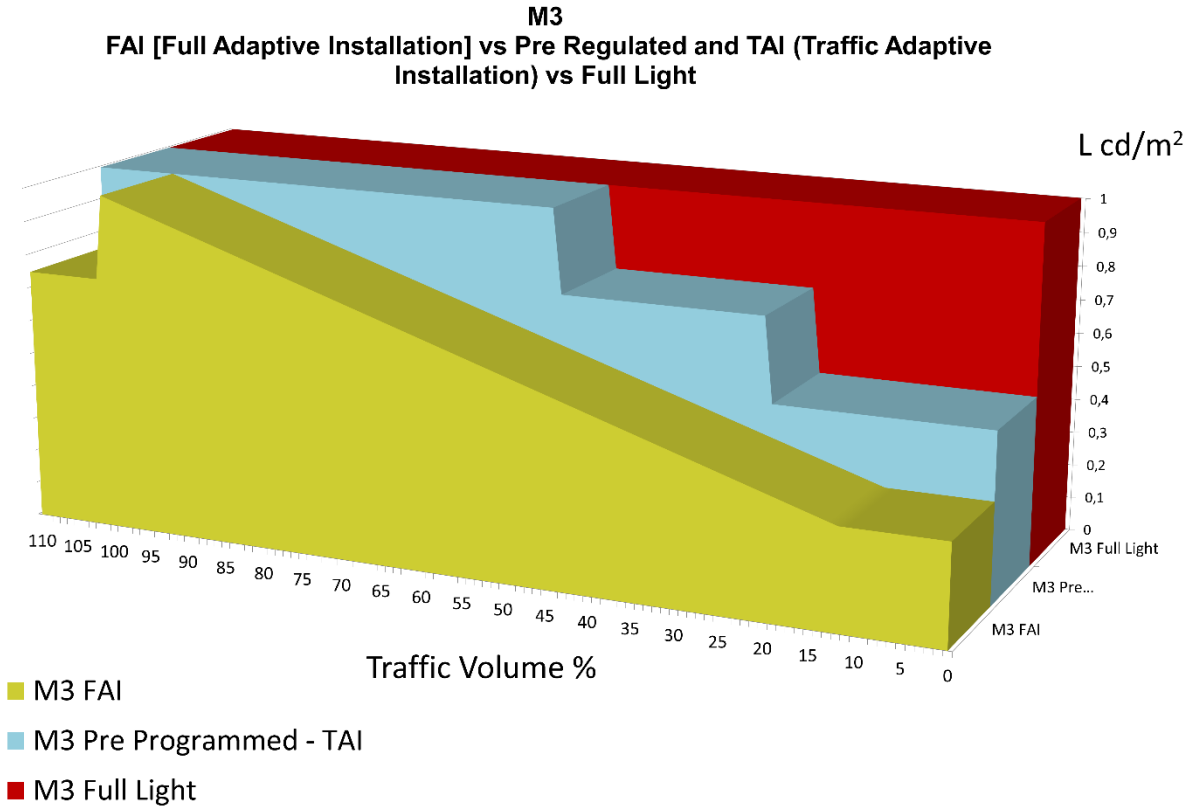


Figure 1 Lighting Strategy - Luminance levels comparison

TESTING SCOPE

LIFE-DIADEME consortium installed the Piacenza testing site to evaluate the adaptive lighting system performances in a medium-size urban environment.
Piacenza test site has Solid-State Light (LED) installed along the test road, and Lighting points are relatively new. In 2018, Citelum installed 30000 new lighting fixtures all around the city.
The LIFE-DIADEME consortium used a small part of this vast luminaries plant to test the adaptive lighting strategy.
Citelum remotely controls all the Piacenza lighting points. A statistical dimming method it's generally applied on all the LED lighting points. We can consider the Piacenza test site as a state-of-the-art public lighting plant.
Different plants worldwide are now working with LED lighting fixtures, and some are saving energy thanks to a pre-programmed dimming strategy, as in Piacenza.
Testing adaptive lighting technology in Piacenza allowed the LIFE-DIADEME consortium to validate the novel system on a state-of-the-art plant in a representative mid-sized city of northern Italy.

The consortium validated the system on a total of 76 lighting points equipped with LIFE-DIADEME electronics.
LIFE-DIADEME consortium, thanks to this test site, would demonstrate that:

- an adaptive system can regulate lighting levels thanks to real-time traffic detection and real-time luminance levels.
- Adaptive lighting can perform an energy saving of at least 30% if compared with, as defined by UNI11431, a statistically pre-programmed lighting cycle (state-of-the-art technology at project start-up time).

- The diffused system can collect valuable traffic volume information.
- Such a system provided with noise measurement capability can significantly support municipalities involved with the Directive 2002/49/EC of the European Parliament about noise detection.
- Low-cost air quality devices can provide diffused data helpful in setting up plans to help local authorities achieve clean air, as requested by the Clean Air Program for Europe.
- LIFE-DIADEME system will provide meaningful information to stakeholders on the Distributed Adaptive Lighting strategy, single roads traffic volume, diffused environmental noise and air quality levels, enabling the Smart City.

TEST SITE OVERVIEW

Piacenza is a city in the northern Italy Emilia-Romagna region, the capital of the eponymous province.
Piacenza is a significant crossroads with Route E35/A1 between Bologna and Milan and Route E70/A21 between Brescia and Turin. Piacenza is also at the river Trebbia's confluence, draining the northern Apennine Mountains, and the Po, draining to the east. Piacenza also hosts two universities, Università Cattolica del Sacro Cuore and Polytechnic University of Milan.
Piacenza cover an area of 118 km^2 with a population of 103000 inhabitants

By the end of 2019, the Municipality of Piacenza signed an agreement with the LIFE-DIADEME consortium to provide a small test helpful site to evaluate system performances and smart city data acquisition.
With Citelum EDF's support, the consortium designed the test site along with Via Primo Maggio.
The testing site is a double carriageway, double lane road along the perimeter area of the city.
The consortium designed the test site rapidly, and by the end of January 2020, documentation was ready for installation and material was supplied to Piacenza for placement.
COVID-19 pandemic shifted the installation from the middle of February 2020 to the centre of July 2020.
By August 2020, the system was settled up and properly working.
LIFE DIADEME consortium installed along Via Primo Maggio in Piacenza the following devices:

- 76 LIFE-DIADEME
- 2 LTM devices
- 2 Air Quality sensors
- 2 Air Quality sensors above the ARPA cabinet

To more profoundly evaluate air quality sensors' response, the LIFE-DIADEME consortium organised a collaboration with ARPA Emilia Romagna.
The consortium was able to install, directly above the ARPA cabinet, two air sensors systems. We installed the first system in the centre of Piacenza (Via Giordani) and the second one in a green area outside the city (Parco Montecucco). In this way, the consortium explored different gas concentration sensitivity: one set for the traffic zone and the other for the background zone.

Figure 2 Piacenza Test Site By Night

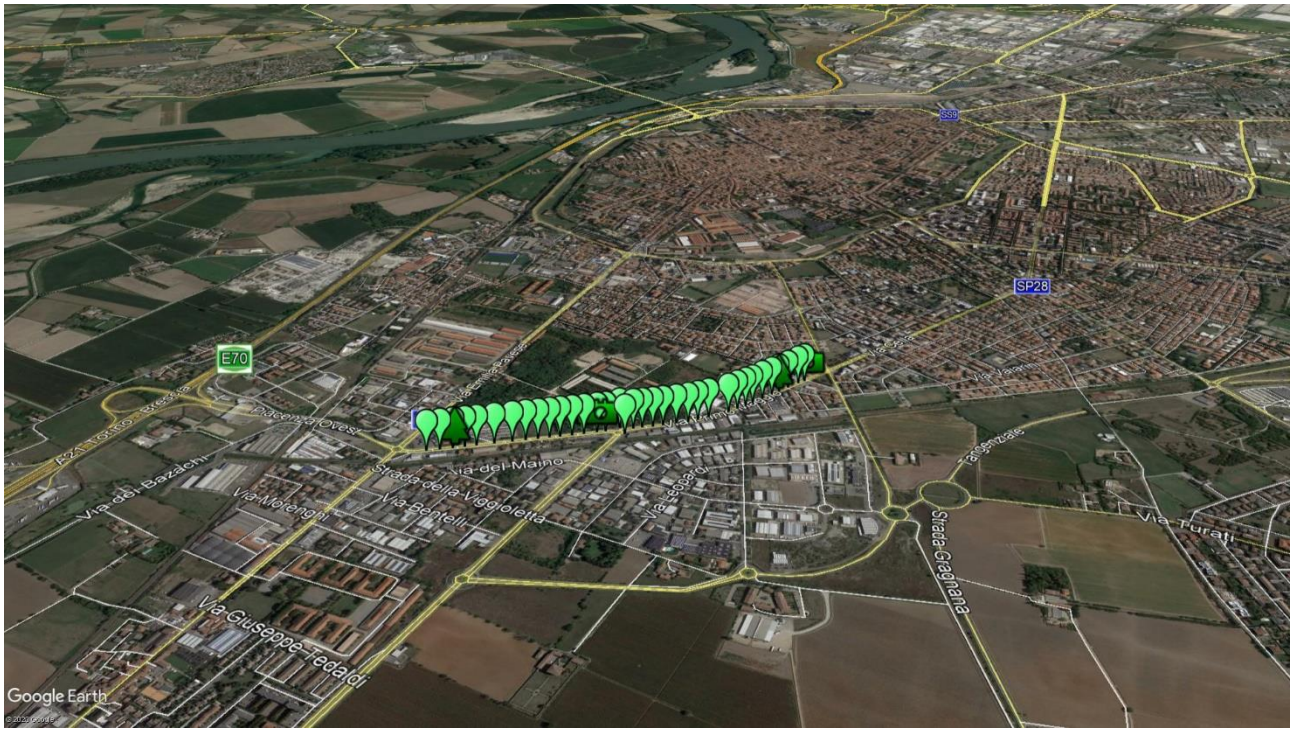


Figure 3 LIFE-DIADEME Piacenza Test Site Full Installation

Figure 4 Piacenza LIFE DIADEME installation

Figure 5 Specialized Devises Piacenza installation

Figure 6 Air Quality

Figure 7 LTM

Figure 8 Air Sensor ARPA Via Giordani

Figure 9 Air Sensor ARPA Parco Montecucco

ENERGY SAVING

Citelum EDF installed LIFE-DIADEME system in Piacenza during July 2020.
Setup activities were going on until 25 August 2020.
On 25 August 2020, the consortium settled in operation mode the LIFE-DIADEME Adaptive lighting system.
To better understand Piacenza results, it's essential to underline the main difference between the Adaptive Lighting operation mode, the LIFE-DIADEME consortium wanted to test, and what consortium settled up for the test site.
From Piacenza municipality, the consortium received the green light to proceed with the adaptive lighting test.
To mitigate a personal threat related to street lighting reduction, Piacenza technical manager required a fundamental constraint: lighting level can't be reduced as low as UNI11248 permits for Full Adaptive Lighting system, 0,3 cdm^2, but only down to a minimum level of 0,7 cdm^2.
Municipality constraints, de facto, had an essential impact on the energy savings the LIFE-DIADEME system can reach if fully developed.
From this point of view, energy savings performed by the Piacenza test site must be considered as upgradable to a higher level if a full UNI11248 compliant adaptive lighting it's executed.
Figure 10 explains the real scenario applied along with the Piacenza test site. When traffic is considerably small, the automatic system reduces the street luminance level to a constant value near 0,7 cd/m^2 instead of 0,3 cd/m^2. The increased lower limit luminance is the direct consequence of Piacenza municipality constraints.
Figure 11, the blu rectangle, explains how much energy the LIFE-DIADEME can successfully save if the Full Adaptive method can properly work without luminance limits.
Disclosed data were acquired using the DIADEME LTM system, a computer vision technology able to detect real-time traffic, luminance level and weather conditions.
The green line represents the luminance level driven by the LIFE-DIADEME adaptive system following the municipality restrictions.
The method, reading the actual traffic conditions, can set a lower luminance level. The yellow line, referring to UNI1248, indicates the luminance level the system can adequately reach.
In blu, the real-time traffic level.
We can observe that the system doesn't permit a light level lower than 0,7 cdm^2. More efficient regulation is possible, and the rectangle in the picture centre evidences this.
The minimum lighting level constraints profoundly impacted the maximum energy savings a system like LIFE-DIADEME can provide to a city.
From the consortium point of view, using the full performance of the LIFE-DIADEME system, the plant can provide more energy-saving than the one measured on the Piacenza Test Site.

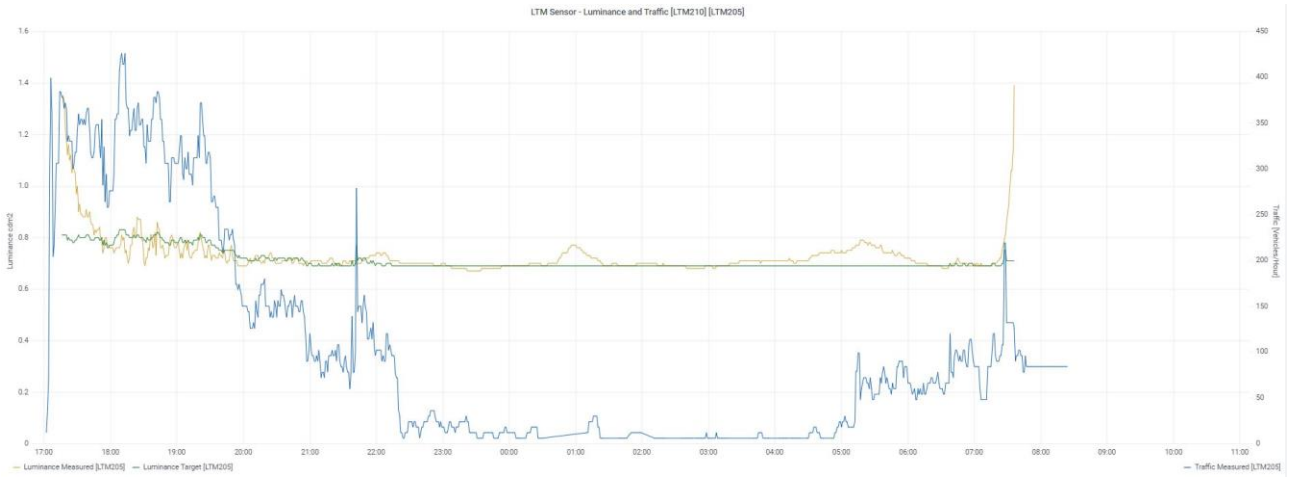


Figure 10 Light Control with lower limit at 0,7cd/m²

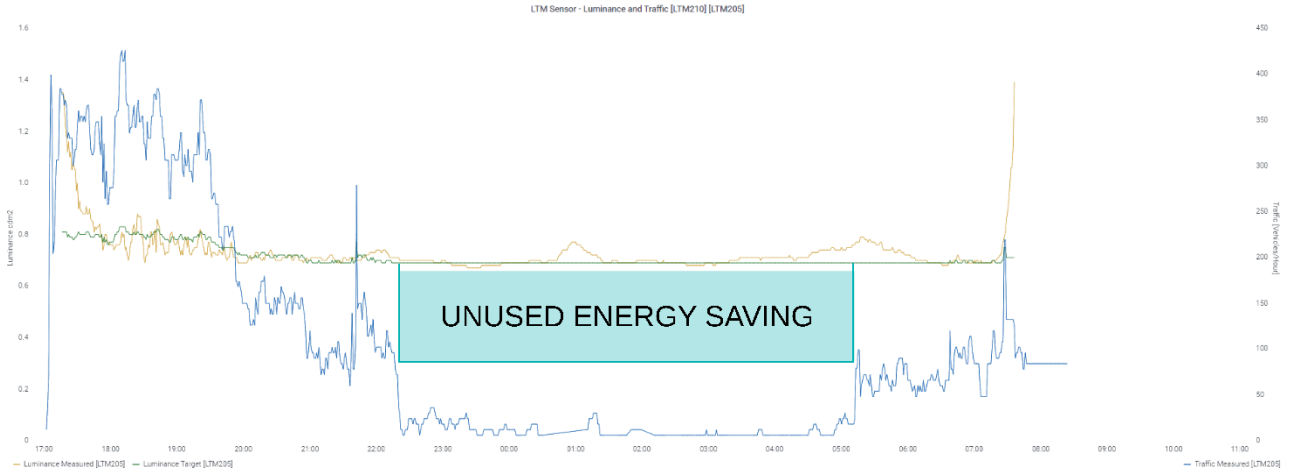


Figure 11 Piacenza Adaptive Lighting example with Full Adaptive regulation

For just one night, from 6 to 7 September 2020, the LIFE-DIADEME consortium tested the full adaptive lighting capability, pushing down luminance levels to 0,3cdm².

Figure 12 Full UNI11248 Full Compliant test

A comparison with the consecutive days, when the system limited the luminance reduction at 0,7 cdm², provided significant results:

	UNI 11248 FULL COMPLIANT NIGHT	NIGHT + 1	NIGHT + 2	NIGHT +3	*AVERAGE*	EXTRA SAVING
Full Light Energy Savings	57.6 %	49.4%	47.5%	49.6%	*48.8%*	8.7%
Pre-Programmed Energy Savings	43.1 %	33.5%	30.0%	33.7%	*32.4%*	10.7%

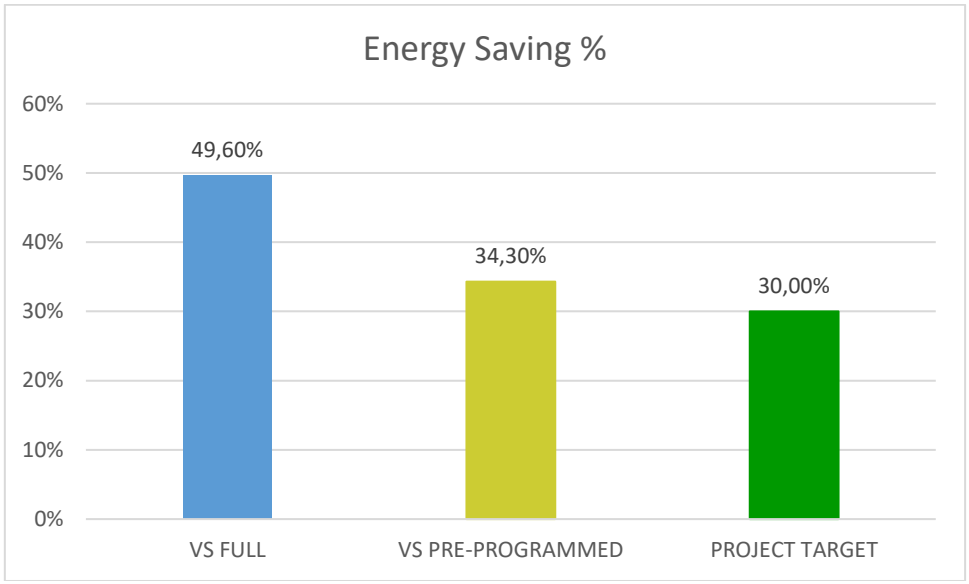
The night the consortium applied the UNI11248 Full Compliant adaptive lighting strategy, the system registered an energy savings increase of 8.7% compared to the full light method.
Data evidence a more consistent 10,7% energy saving if compared to the pre-programmed system.
We can't assume a single night statistic as the ground truth reference, but the result it's concretely interesting.
To validate final results in different conditions, a test on Piacenza's adaptive street lighting system took place for a long time.
The consortium collected from each single installed lighting fixture the consumed energy.
To evaluate LIFE-DIADEME performances, both the state-of-the-art lighting system (pre-programmed strategy) and the full light system, the LIFE-DIADEME consortium used statistical data directly co-related with in-field installed lighting points.
It's interesting to understand how the adaptive lighting strategy can perform if applied on a similar plant without any energy-saving process. For this reason, in this document, there is the voice "FULL LIGHT" that represents such a lighting plant.

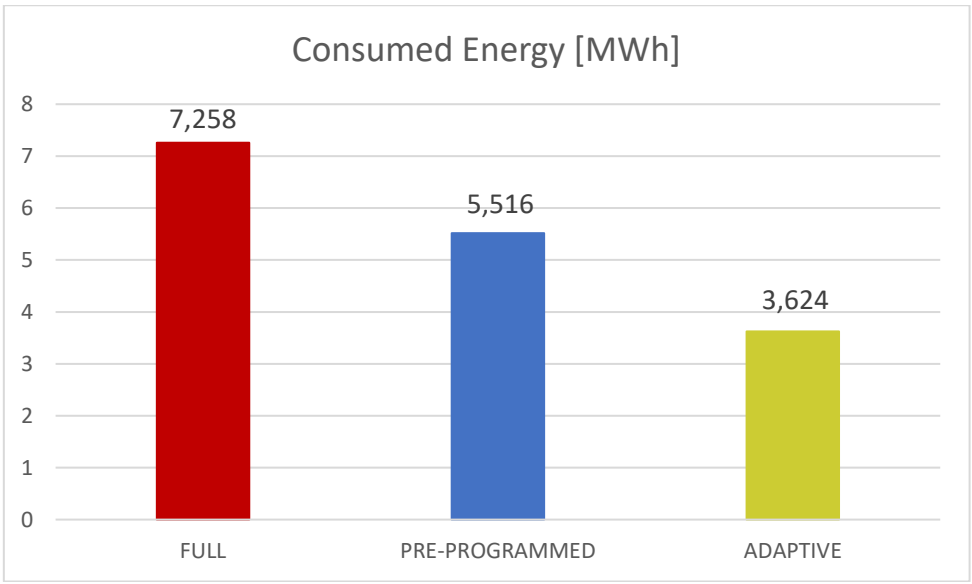
Piacenza LIFE-DIADEME site performed better than the 30% energy savings project target.
The LIFE-DIADEME adaptive system, even with a lower dimming capabilities limit, compared with the pre-regulated strategy, provided an energy savings of 34.3% during the test period.
Compared to the full light strategy, results along the same period provided an energy savings of 49.6%.

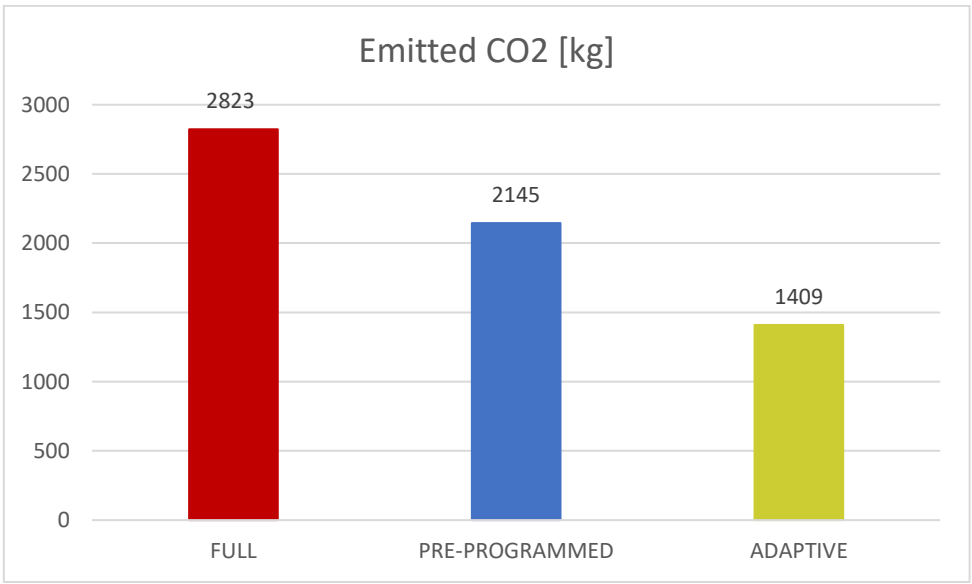
Results confirmed that an adaptive system lighting plant could provide significant energy saving, considerable GHG emission and a lower production cost for street lighting functionality.

	Consumed Energy [MWh]	**Emitted CO2 [kg]**
FULL LIGHT	7,258	2823
PRE-PROGRAMMED	5,516	2145
ADAPTIVE	3,624	1409

	Energy Saving %	**Saved Energy [MWh]**	**Saved CO2 [kg]**	**Saved Costs [€]**
VS FULL	49,60%	3,6	1400	€ 643
VS PRE-PROGRAMMED	34,30%	1,7	676	€ 305
PROJECT TARGET	30,00%	1,65	644	€ 297


Energy Saving %
60%
50%
40%
30%
20%
10%
0%
49,60%
34,30%
30,00%
VS FULL
VS PRE-PROGRAMMED
PROJECT TARGET


Consumed Energy [MWh]
8
7
6
5
4
3
2
1
0
7,258
5,516
3,624
FULL
PRE-PROGRAMMED
ADAPTIVE


Emitted CO2 [kg]
3000
2500
2000
1500
1000
500
0
2823
2145
1409
FULL
PRE-PROGRAMMED
ADAPTIVE

TRAFFIC MONITORING

The system performs a 24/24h traffic level detection under each single lighting point equipped with a LIFE-DIADEME device. This full-time acquisition capability it's provided thanks to a battery installed inside each LIFE-DIADEME device.
The battery enables continuous monitoring and communication, and it's recharged overnight once lamps are on. In the early morning, when the lighting plant it's powered off, the smart city system starts working thanks to the stored energy.
By night, once the lighting plant is working, the LTM camera provides the LIFE-DIADEME system to perform traffic count using computer vision algorithms. Computer vision enhances precision about traffic volume data collected. A sophisticated device as LTM can perform processes to identify traffic, weather and luminance in real-time conditions. The system used data acquired both by LIFE-DIADEME devices and LTM cameras to drive street lighting levels according to UNI11248 Technical standards.
In Figure 13 can be observed a picture where's reported the traffic volume along the entire considered period. Data exposed in the graph were collected using diffused traffic sensors of LIFE-DIADEME devices.
The peaks value refers to daytime traffic.
The peak traffic level seems to be near 2500 vehicles/hour.

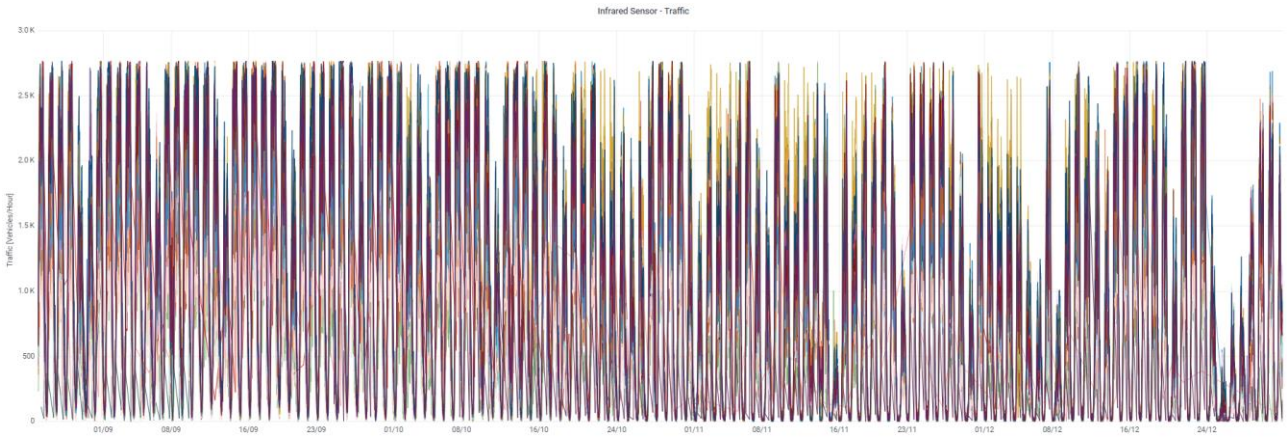


Figure 13 Traffic Volume 25/08/2020 to 31/12/2020

A more detailed evaluation of traffic sampling capabilities can be analysed considering the Christmas holidays period.

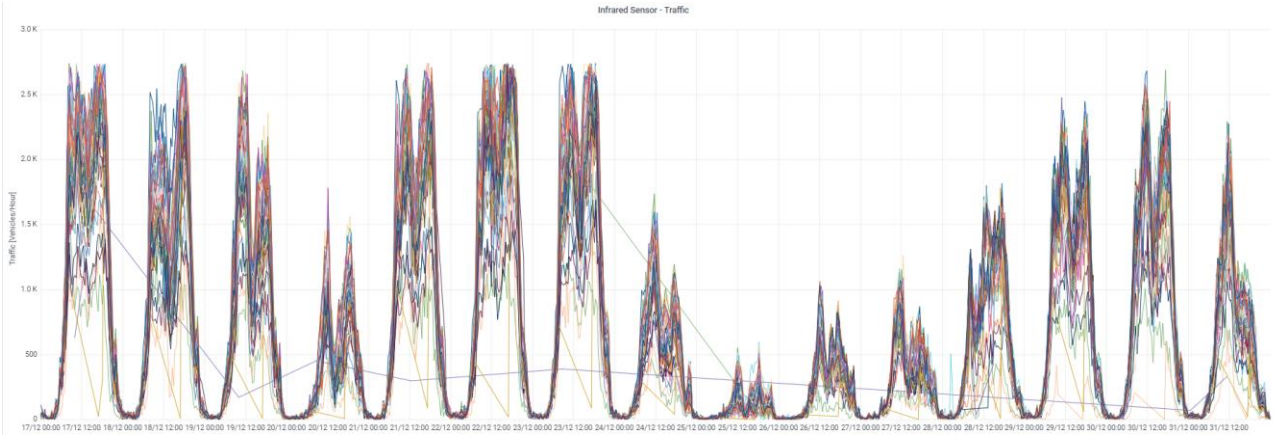


Figure 14 Traffic Volume 17/12/2020 to 31/12/2020

ENVIRONMENTAL NOISE

The consortium equips the LIFE-DIADEME systems with a low-cost sensor to collect environmental noise around the lighting point. Each electronics board can perform a dedicated evaluation of background noise and peak noise, using a correction curve to model human audio behaviour.
System providers can use diffuse noise detection to support municipalities in the direction of directive 2002/49/EC of the European Parliament and the Council of 25 June 2002 relating to environmental noise assessment and management.
This Directive shall aim to define a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to exposure to environmental noise. A municipality, to reach the Directive targets, should implement progressively:
(a) the determination of exposure to environmental noise, through noise mapping, by methods of assessment common to the Member States;
(b) ensuring that information on environmental noise and its effects is made available to the public;
(c) adoption of action plans by the Member States, based upon noise-mapping results, to prevent and reduce environmental noise where necessary and significantly where exposure levels can induce harmful effects on human health and to preserving environmental noise quality where it is good.

The consortium doesn't design the LIFE-DIADEME noise acquisition system as a replacement for calibrated instrumental measurements requested by the Directive. The target of a diffused environmental noise acquisition, working 24/24h, is to provide the municipality with helpful information about ecological noise in different zones and districts. The system, continuously monitoring space around the lighting plants, provide supervision for human safety and environmental conditions.

Every single device provides for a continuous noise sampling audio parameters.
The LIFE-DIADEME system evaluates a parameter easy to understand by citizens: the Harmonica Index.
Harmonica Index t's the final result of the LIFE-HARMONICA project.
The HARMONICA project (Harmonised Noise Information for Citizens and Authorities) had several objectives:

- make information on noise more accessible and closer to people's perceptions by eliminating the technical terms that are difficult for laymen to understand.

- Assess noise abatement actions harmonised and promote practical steps to help the authorities draw up their action plans to implement the 2002/49/EC Directive.
- Facilitate the transfer of this approach to European cities to support the policies in place better to reduce environmental noise and improve access to information for the general public.
- Contribute to developing a common and shared culture allowing everyone to understand the noise better.

The development of a simple index for presenting environmental noise levels should meet particular concerns:

- Ease of understanding by the general public as operating on a scale from 0 to 10, rather than decibels.
- A simple calculation of environmental noise from in-field measured data.
- Calculate for one-hour time slots represent the index changes over a day, and derive average results over any periods (day, night, 24 hours, week, month, year).
- Considering two significant components that affect the noise environment: background noise and noise events that exceed this background noise (noise peaks).
- A concrete representation of people's perceptions of their noise environment more than do the indicators currently used in the European regulations.

LIFE-DIADEME system, using the output of LIFE-HARMONICA, provides noise level on a scale from 0 to 10, where 0 it's the silence, and 10 represents an intense noise.

Acquired data shows a low noise activity in the monitored area. Values below 4 represent a quiet environment. From Figure 15, we can observe that daily noise is higher than night noise, as expected if compared with road traffic and human statistical activities.

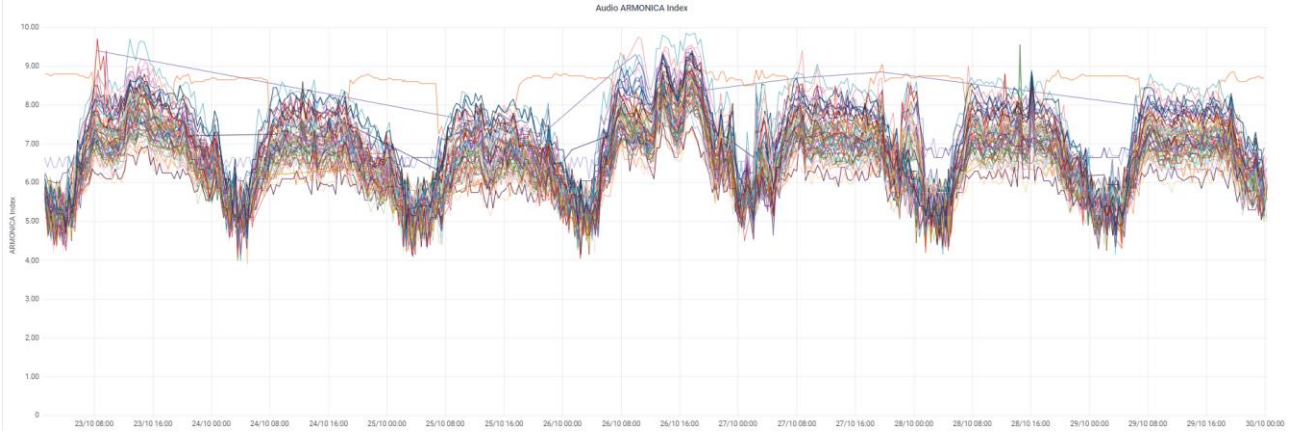


Figure 15 Harmonica index 23/10/2020 to 29/10/2020

Environmental Noise – In Field measurement

On 22 October 2020, the LIFE-DIADEME consortium organised a noise measurement campaign on the Piacenza test site.
The measurement of acoustic noise level it's a time-consuming activity. As prescribed by technical standard, a sample it's acquired every 15 minutes. The tester, to obtain significant noise level measurement, should get different audio samples.
The consortium has bought a portable audiometer to realise in-field noise measurement acquisition.

Measurements took place along Via Primo Maggio, near a french roundabout.
We settled up the audiometer station following the technical directive requirements: 1,5m from ground level, targeting the street direction.
To evaluate LIFE-DIADEME system performances, we have compared acquired data from the lighting point devices with the data obtained by the certified audiometer.

Figure 16 Audiometric Test Setup

Data comparison between the certified audiometers and the LIFE-DIADEME noise acquisition system is fascinating.

The following Figure 17 represent different Harmonica Index measurements.

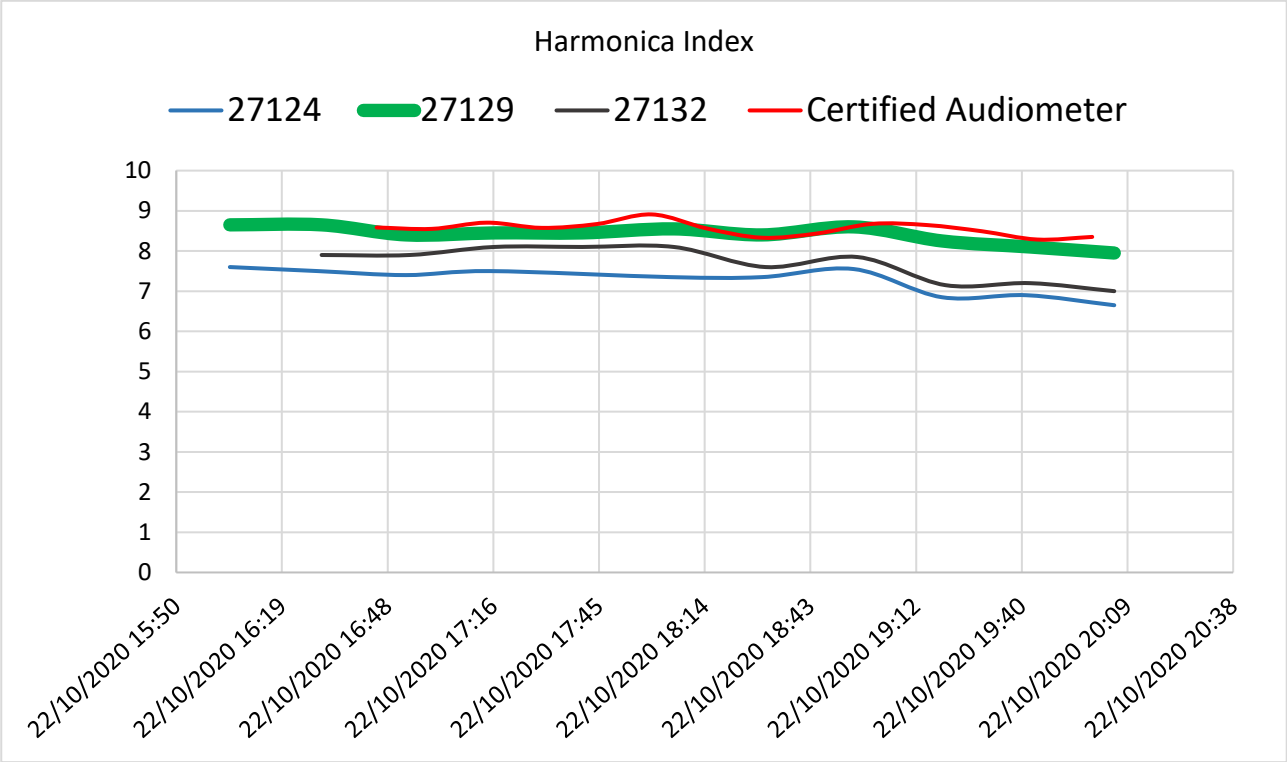


Figure 17 Harmonica Index Evaluation

Noise Results

The main objective of the LIFE-DIADEME consortium, about noise evaluation, was to test a system able to support the municipality in the tasks required by the Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise.
The main idea was to provide a noise map with an accuracy of ±5% of the maximum range of 80db.

Considering only phonometric values collected by LIFE-DIADEME 27129, the device installed above the area interested by certified measurements achieve project targets.

Data collected by different lighting points all around the Piacenza test site, as previously shown, indicates that we can consider the information collected by the system of great value.
To provide a heatmap representation of the noise level captured under each lighting point, using the LIFE-DIADEME system can be considered a unique solution for the municipalities.

Figure 18 Noise Measurement With Certified Audiometer

AIR QUALITY DETECTION

Air Quality Installation

For the LIFE-DIADEME Piacenza site, the consortium installed a total of 4 quality air detection units.
Citelum EDF installed 2 Air Quality systems along via Primo Maggio, the street involved in the LIFE-DIADEME test.
Thanks to the collaboration with ARPA Emilia Romagna, The consortium had the opportunity to install two detection units directly above different ARPA cabinets: one in the centre of Piacenza (Giordani -Farnese – Traffic station) and the other one, inside a park near the external perimeter of the city (Parco Montecucco – background station).

Figure 19 Air Quality Systems Piacenza Site

All the Air quality Systems mounts low-cost sensors to acquire concentration of CO, NO, NO2, O3, atmospherical pressure, relative humidity and temperature.
Thanks to the experience acquired by Roma air quality devices, the setup of Piacenza air quality devices, if compared to what the consortium made for Rome test site devices, was slightly different.
Before the delivery to Piacenza, Reverberi changed some electronics settings and performed a single system calibration.
In Piacenza, the consortium installed a total of four calibrated air quality systems in July 2020.

Air Quality Detection Results

Compared with ARPA Emilia Romagna's reference values, low-cost data gave outstanding relative error results.
The project target was to provide the municipality with a low-cost instrument to monitor and inform the decision-maker about air quality levels in different city zones.

Such affordable and reliable technology enables the municipality to project an air quality detection network.
A so designed diffused air monitoring system can return feedback on developed actions to mitigate pollution emission in well-defined zones.
We can consider a system with less than 30% of error helpful support to monitor and plan urban pollution strategies. It's the preferred choice to support mitigation strategies and evaluate the results of different developed pollution activities using diffused and low-cost air quality systems.

The LIFE-DIADEME low-cost sensors, if compared with ARPA data, exposed impressive results.
Along the testing periods, measurement errors on different gases concentrations were always less than 10%. If we focus on the lower temperature period, acquired data provided exciting results, reducing the error and increasing the accuracy.
About the project target, the unit tested in Piacenza fulfil the project targets.

The consortium will consider the opportunity of further investigation of how different gas concentrations, temperature, humidity, and atmospheric pressure influences acquisition.

CONCLUSIONS

LIFE-DIADEME system tested in Piacenza provided better energy and GHG savings results if compared with the project targets.
Even with limitations on dimming capabilities, the adaptive system performed a 34.3% energy saving in the monitored period, going beyond the 30% fixed as project target.
This way, such a system can push, in street lighting application, energy savings and security well beyond current state-of-the-art limits.
A system like LIFE-DIADEME can be considered an exciting opportunity to reduce energy consumption and GHG emission in all street lighting applications.
Even more, the system data acquisition capabilities of the Piacenza test site was able to exploit real-time traffic condition, collecting valuable information about traffic volume along Via Primo Maggio. The municipality can use data to project the urban viability with a different perspective and supported by in-field records.
The municipality can mix environmental noise and air quality levels to organise the city in a more eco-friendly way.
Acquired data on a single road can provide disruptive innovation. It's awe-inspiring that sensations about noise, traffic and air quality are finally measured. Real numbers provide the metric to measure the results from performed actions.
From consortium evaluation, LIFE-DIADEME in Piacenza fully achieved all the project targets.