C.2.2 Large scale in-field test pilot report

DIADEME LIFE15 CCM/IT/000110
TEST REPORT
ROMA LARGE TEST SITE
May 2018 – December 2020

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Contents

DOCUMENT PURPOSE

This document explains the LIFE-DIADEME ROMA Large Scale In Field Test Pilot site status.
This document contains detailed information about installation, status, and results involving Rome's more extensive test site.
The Roma large test site involved different streets of Roma E.U.R. and a part of Roma Pietralata district.
This site is the more extensive test site the LIFE-DIADEME consortium installed along with the project duration.

LIFE-DIADEME ROME 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.
As an institutional supporter of the LIFE-DIADEME project, ROMA CAPITALE collaborates with the consortium, allowing systems installation along city streets.
Along the project period, the consortium actively operates with the Rome municipality to involve the decision-maker in supporting project activities and collecting data provided by the in-field systems.

Al the data collected by the LIFE-DIADEME system, from the project end date, have become a municipality digital property. The main difference between Rome and the other two decision-makers is the way they use the data. ROMA CAPITALE is an active player in data acquisition and use.
All the Rome smart city data are collected from different streets and from many in-field servers able to perform local data collection and system management.
Due to the complexity of the large test site in Rome, the consortium switched on the adaptive lighting method on different plants in a period from October 2019 to March 2020.
By the end of 2020, The consortium commissioned 80% of the large test site lighting points and programmed the system to work with an adaptive lighting strategy.
The heterogeneous complexity of Roma E.U.R. and Roma Pietralata provided an ideal base to test different roads typology about the luminance level road category.
The street lighting categories listed in Rome are M2(fast and high traffic volume), M3 and M4 (urban and low traffic volume) classes.
In the following graphs, the different profiles we applied by class.

M2

- Nominal Luminance Level: 1,5 cd/m^2
- Maximum Road Traffic: 1100 vehicles/hour
- UNI11248 Full Adaptive Lighting – Minimum Luminance Level: 0.5 cd/m^2

Figure 1 visually exposes different luminance levels depending on the street lighting strategy for an M2 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.

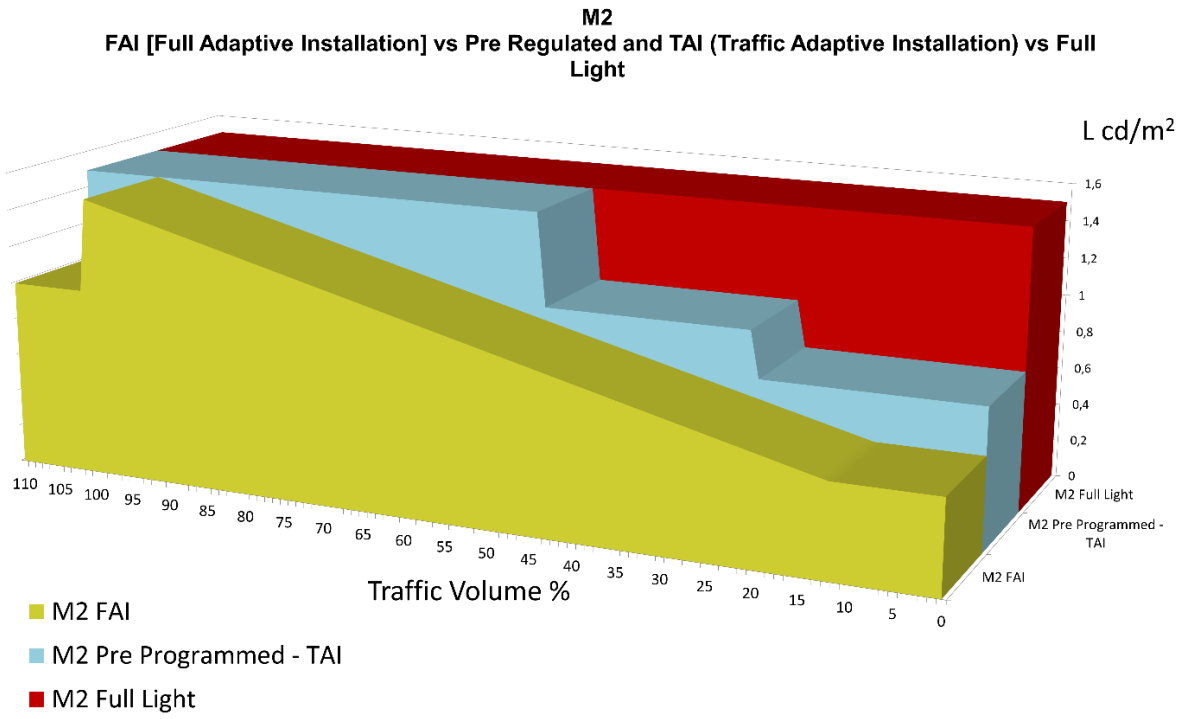


Figure 1 Lighting Strategy – M2 Luminance levels comparison

M3

- 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 2 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.

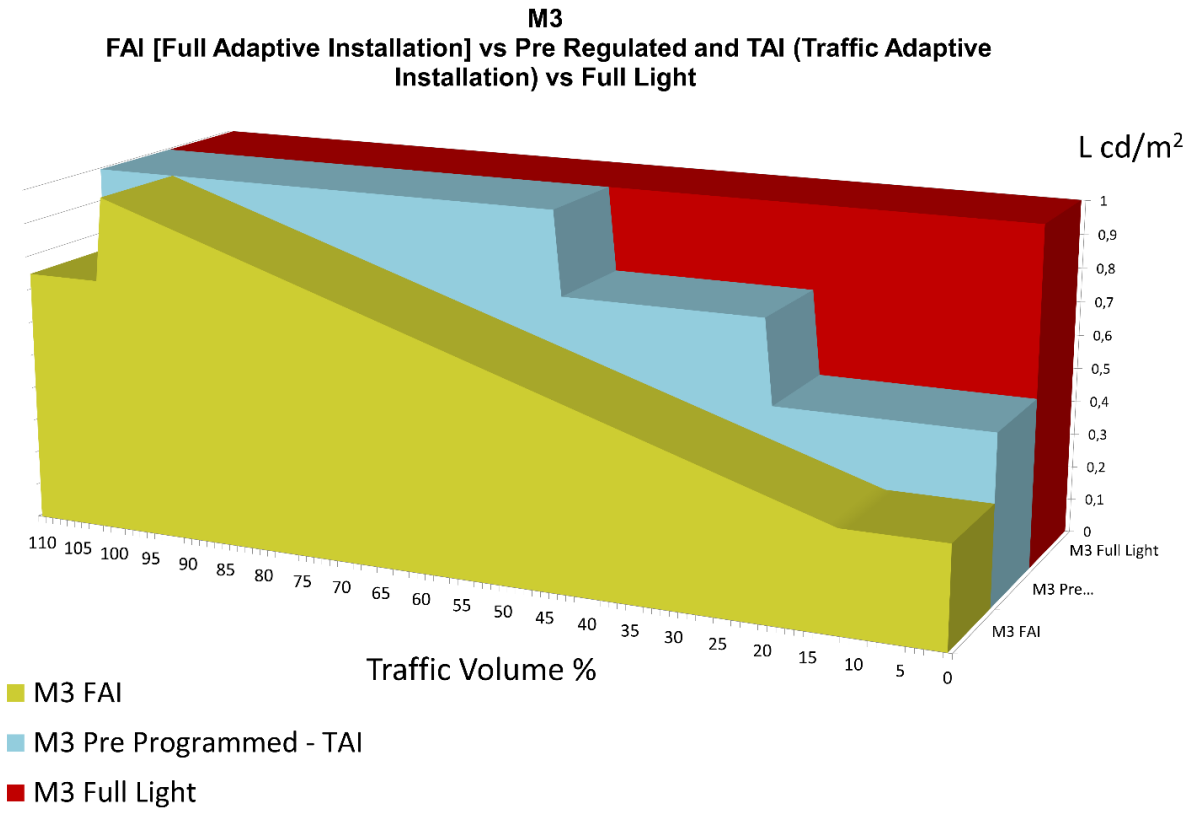


Figure 2 Lighting Strategy – M3 Luminance levels comparison

M4

- Nominal Luminance Level: 0.75 cd/m²
- Maximum Road Traffic: 600 vehicles/hour
- UNI11248 Full Adaptive Lighting – Minimum Luminance Level: 0.3 cd/m²

Figure 3 visually exposes different luminance levels depending on the street lighting strategy for an M4 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.

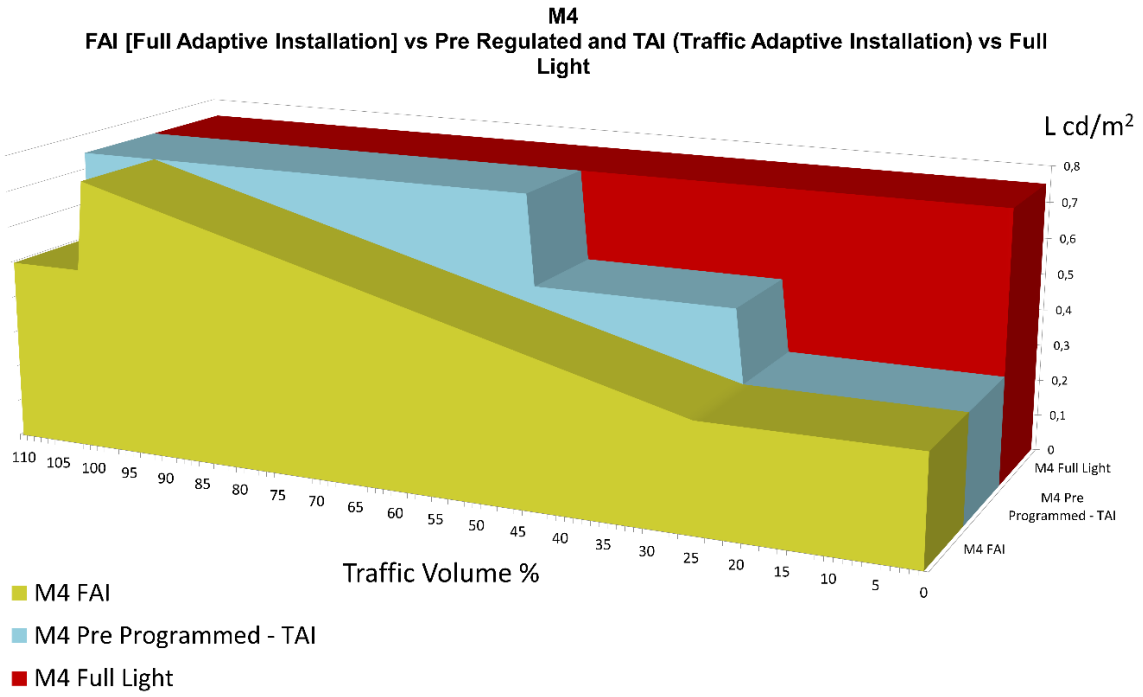


Figure 3 Lighting Strategy – M4 Luminance levels comparison

TESTING SCOPE

LIFE-DIADEME consortium installed the Roma Large test site to evaluate the adaptive lighting system performances in a medium-size urban environment.
The consortium organised and settled up this extended site thanks to the information and experience achieìved by the 108 lighting poles from the Small Test Site. We can observe an essential review of electronics and mechanics between the small test site and large test site systems. The consortium used all the small test site experience information to reduce costs, reduce the external size, and simplify the installation.
Roma Large test site it's based on SSL (Solid State Lamp is also known as LED). This technology's state-of-the-art public lighting systems.
As explained for the Small Test Site, each lighting point has a Reverberi Enetec communication system on it.
The test site in the Italian Capital city it's organised to assess adaptive lighting and innovative city capabilities in a complex environment.
The Roma E.U.R. area it's a multi-environment system. The headquarters of many important companies are at EUR. "La Nuvola", a futuristic congress centre, it's in the heart of the EUR district, and different aggregate activities surround the building. It's also a residential zone with condominiums and villas. There are also various shopping activities along some dedicated streets, and the Roma E.U.R. 2, the biggest city mall, it's inside the district.
On the other side of Rome, there is the Pietralata district. We installed a small part of the LIFE-DIADEME large test site along the Pietarlata streets. Pietrlata is a typical residential district of Rome. The devices installation zones are near schools and a swimming pool. The environment's significantly different if compared with Roma E.U.R., and it's interesting to evaluate the system behaviour in this kind of application.
In this report, to better evaluate the different city zone, we will separate the evaluation of Roma Eur and Roma Pietralata systems.

ROMA CAPITALE has a total of 240.000 lighting points. The LIFE-DIADEME consortium used a small part of this enormous luminaries plant to test LED technology's adaptive lighting strategy.
Different plants worldwide are currently working with a pre-programmed dimming strategy, for example, Rimini and Piacenza.
Testing adaptive lighting technology in Rome allowed the LIFE-DIADEME consortium to validate the novel system on an SSL lamp plant representative of a European Capital city.

The consortium validated the system on a total of 796 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 energy-saving method 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/E.C. 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

Rome is the Capital City and a special comune of Italy (named Comune di Roma Capitale) and the capital of the Lazio, a region on Italy. The city has been a primary human settlement for almost three millennia. With 2,860,009 residents in 1,285 km2, it is also the country's most populated comune. It is the third most populous city in the European Union by population within city limits. It is the centre of the Metropolitan City of Rome, which has a population of 4,355,725 residents, thus making it the most populous metropolitan city in Italy. Its metropolitan area is the third-most populous within Italy. Rome is located in the central-western portion of the Italian Peninsula, within Lazio, along the Tiber's shores. Vatican City (the smallest country in the world) is an independent country inside Rome's city boundaries, the only existing example of a country within a city; thus, Rome has sometimes been defined as the capital of two states.
For the Large test site, the LIFE-DIADEME CONSORTIUM installed:

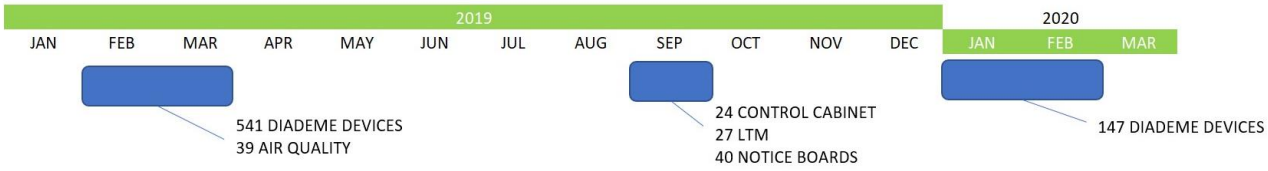
- 688 LIFE DIADEME devices
- 39 Air Quality systems
- 30 LTM computer vision camera

ROMA EUR

The consortium installed the Roma EUR large test site from February 2019 and February 2020.
Following, the data about the installed devices in Roma EUR:

- 614 LIFE DIADEME devices
- 35 Air Quality systems
- 28 LTM computer vision camera
- 40 Notice Boards

The installation took place with the following timing:



The street involved in the Roma EUR Large Test Site installation are:

VIA CRISTOFORO COLOMBO
VIALE DELL'OCEANO ATLANTICO
VIALE DELL'OCEANO PACIFICO
PIAZZALE DELL'UMANESIMO
VIALE DELL'UMANESIMO
LARGO SRI LANKA
VIA NAIROBI
PIAZZA PAKISTAN
PIAZZA GANDHI
PIAZZA GUGLIELMO MARCONI
PIAZZALE DEGLI ARCHIVI
PIAZZALE GIULIO PASTORE
PIAZZALE KONRAD ADENAUER
QUADRATO DELLA CONCORDIA
VIA CHOPIN
VIA CRISTOFORO COLOMBO
VIA LAURENTINA
VIA LISZT
VIA NAIROBI
VIA STENDHAL
VIALE AMERICA
VIALE BEETHOVEN
VIALE BOSTON
VIALE DEI PRIMATI SPORTIVI
VIALE DELL'AGRICOLTURA
VIALE DELL'ARTE

VIALE DELL'INDUSTRIA
VIALE DELL'OCEANO ATLANTICO
VIALE DELL'OCEANO PACIFICO
VIALE DELL'UMANESIMO
VIALE DELLA CIVILTA' DEL LAVORO
VIALE DELLA LETTERATURA
VIALE DELLA MUSICA
VIALE DELLA PREVIDENZA SOCIALE
VIALE DELLA TECNICA
VIALE EUROPA
VIALE PASTEUR
VIALE SANTI PIETRO E PAOLO

Figure 4 LIFE-DIADEME ROMA EUR lighting points Installation

Figure 5 LIFE-DIADEME EUR lighting points installation example

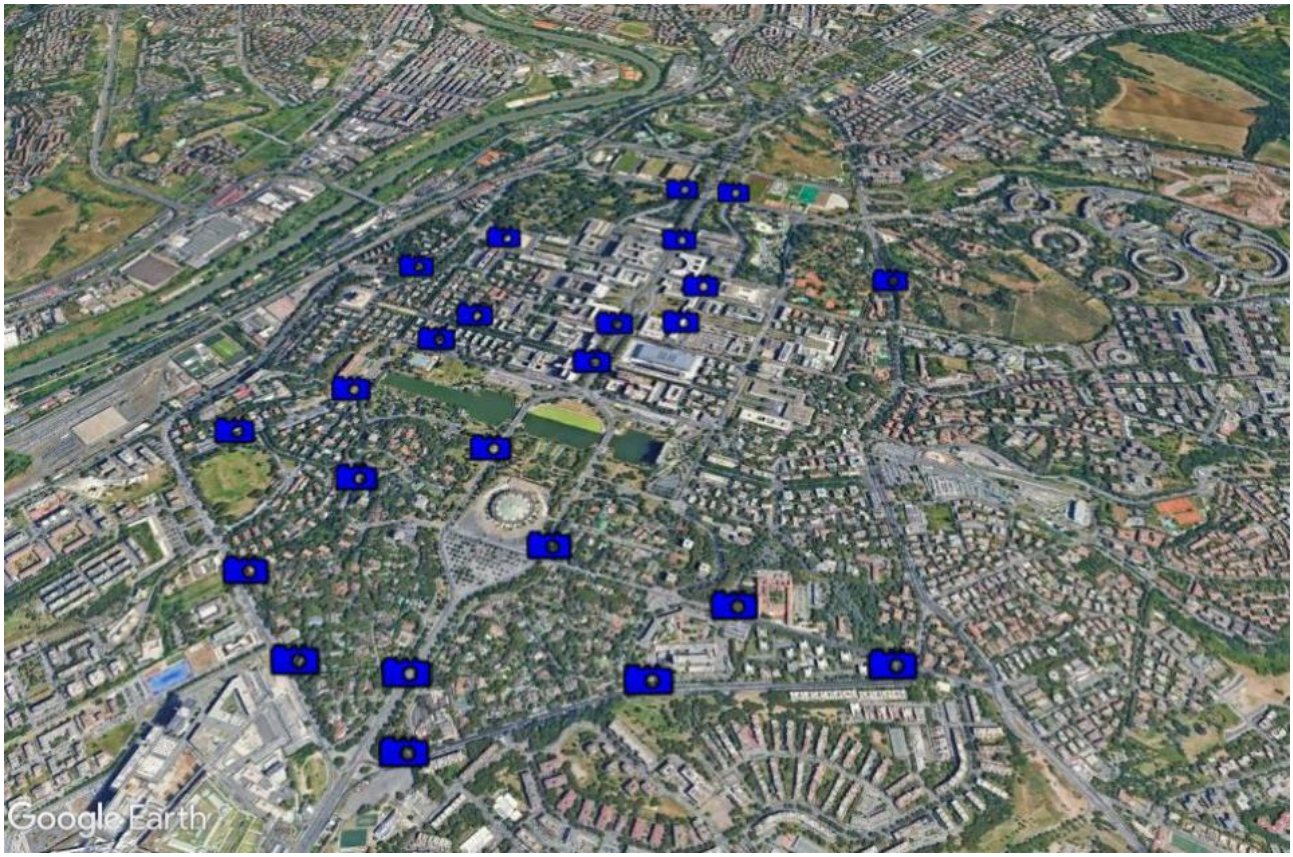


Figure 6 LIFE-DIADEME ROMA EUR LTM Installation

Figure 7 LIFE-DIADEME ROMA EUR LTM example of setting up

Figure 8 LIFE-DIADEME ROMA EUR Air Quality Installation

Figure 9 ROMA EUR Air Quality Example

Figure 10 LIFE-DIADEME ROMA EUR Notice Boards Installation

Figure 11 EUR Example of installed Notice Boards

ROMA PIETRALATA

The consortium installed the Roma EUR large test site in March 2019.
For an in-depth evaluation of air quality sensors' response, the LIFE-DIADEME consortium organised a collaboration with ARPA Lazio.
The consortium installed, directly above the ARPA cabinet and Via Tiburtina, an air sensors system. ARPA Classified this unit as a Traffic Unit.

Following, the data about the installed devices in Pietralata:

- 74 LIFE DIADEME devices
- 4 Air Quality systems
- 2 LTM computer vision camera
- 4 Notice Boards

VIA ACHILLE DE ZIGNO
VIA ACHILLE TEDESCHI
VIA ANTONIO D'ACHIARDI
VIA DEL TUFO
VIA ENRICO SERRETTA
VIA LEOPOLDO PILLA
VIA PRIMO ACCIARESI
VIA VACUNA

Figure 12 Figure 13 LIFE-DIADEME ROMA PIETRALATA lighting points Installation

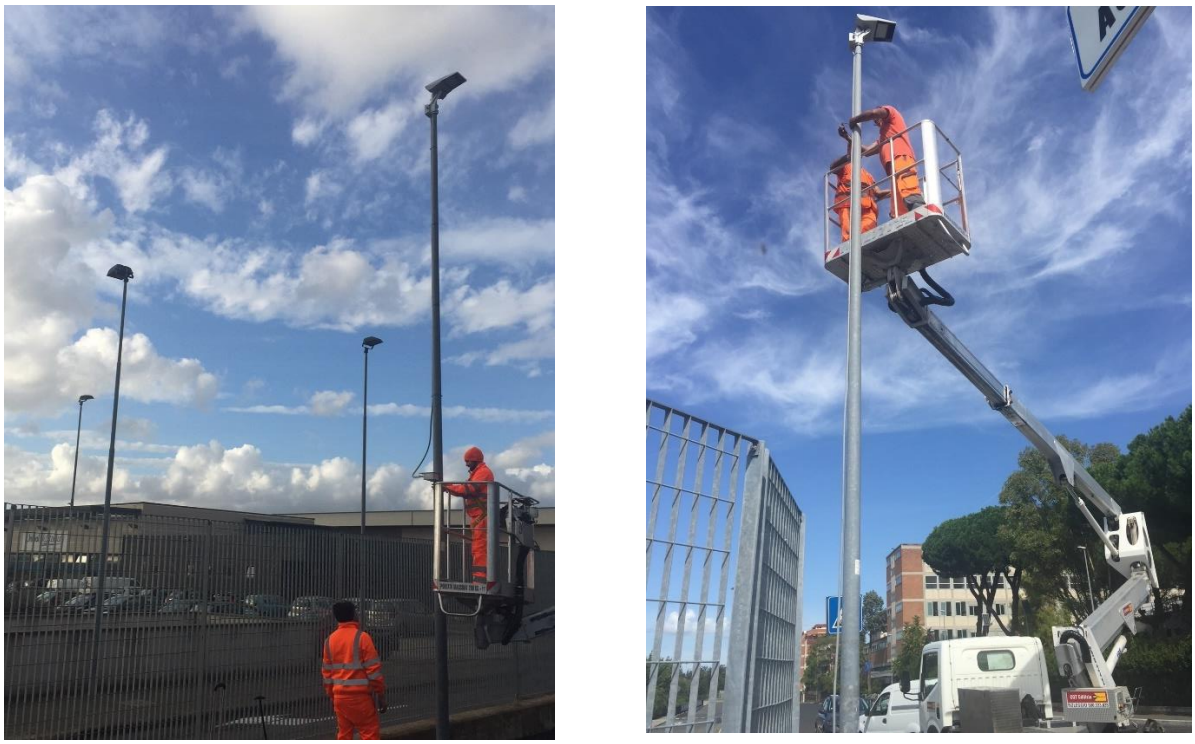


Figure 14 LIFE-DIADEME PIETRALATA lighting points installation example

Figure 15 LIFE-DIADEME ROMA PIETRALATA LTM Installation

Figure 16 LIFE-DIADEME ROMA PIETRALATA Air Quality Installation

Figure 17 ARPA TIBURTINA Air Quality

Figure 18 LIFE-DIADEME ROMA PIETRALATA Notice Boards Installation

Figure 19 Pietralata Example of installed Notice Boards

ENERGY SAVING

As previously exposed, the LIFE-DIADEME consortium installed the Roma Large test site during different periods.
For the consortium, to enable the adaptive lighting method, it was necessary to install the control cabinets.
The control units are the essential element of LIFE-DIADEME systems. Thanks to the capability inside each control cabinet, data from the in-field sensors are collected. At this point, with all the valuable information acquired, the unit it's able to decide the lighting level it's necessary to flow on the street.
Another main task entrusted to the control unit it's the capability to perform the remote connectivity. This feature enables the data download to the main servers and permits lighting plants' setup from everywhere is present internet access.
The consortium installed the control cabinets by the end of September 2019. That time was a milestone in plant setup and configuration.
In the same period, the consortium installed LTM devices along with the Roma large test site plant. These components are an essential reference for adaptive lighting and traffic monitoring. The computer vision algorithm inside each LTM device provides the reference values for real-time luminance, traffic volume acquisition and weather conditions on the streets.
Starting from the end of September 2019, the consortium progressively turned on adaptive lighting and Rome large test site.
Commissioning ended on March 2020 when finally installed the last LIFE-DIADEME devices along with Roma EUR.
As previously exposed, lighting plants are typically exercised at full light in Rome without any energy-saving strategy.
The LIFE-DIADEME consortium operates a game change approach to Rome's lighting plant's large test site, providing new era lighting methods.
Each single lighting point power was classified. This operation was necessary to evaluate energy-saving provided by the adaptive lighting system numerically.
Thanks to this training power activity, the consortium performed a large test site's power mapping before turning on the adaptive energy-saving strategy.
We used the power acquired from every single lamp to perform energy evaluation along one working night. To evaluate the pre-programmed energy on the same night, we calculated the power along night has if a statistical approach drove it.
Similarly, we have applied the same strategy to collect data about the full-light method. In this case, the evaluation of single night energy it's simple: same power along the night.

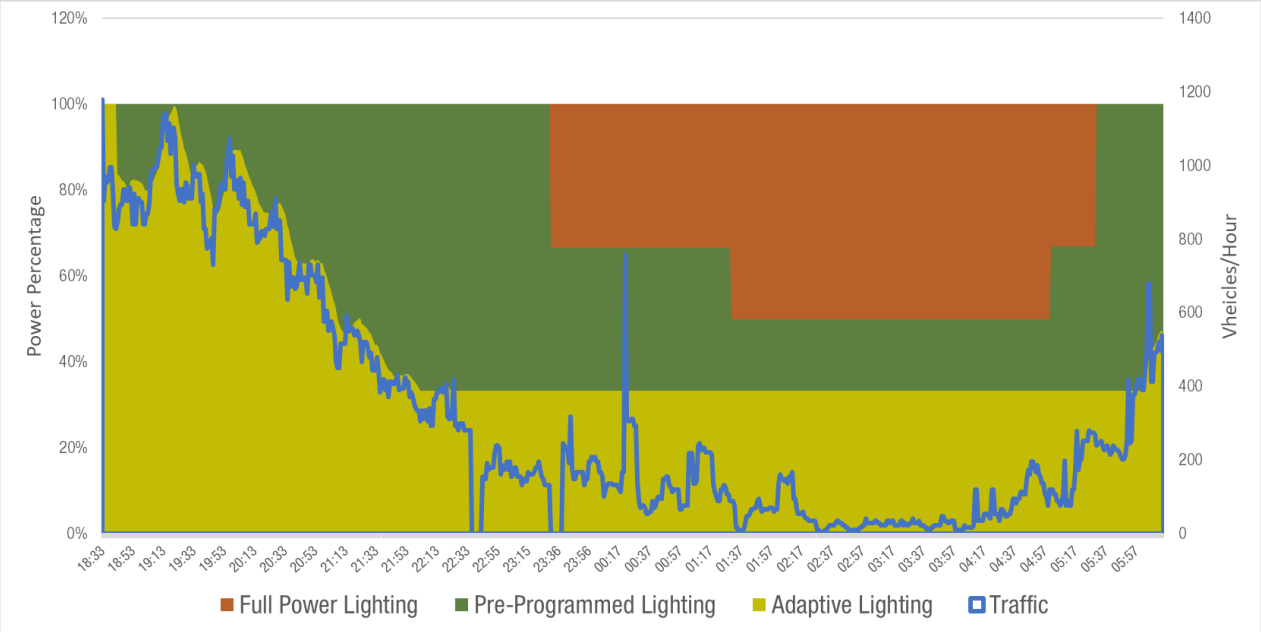


Figure 20 Example of Different energy strategies and traffic values

Figure 20 visually explains the energy consumed by the same lighting plant with different energy strategies.
The information about traffic volume directly drives the luminance reference and, consequently, the lighting plant power level.
In brown, the full-light method: the system is always at maximum power during the night.
In dark green, the pre-programmed strategy. A technical directive statistically evaluates the traffic volume. From this estimation, the public lighting service provider can manage a light reduction at established times. In light green, the adaptive lighting method, tested in an urban environment by the LIFE-DIADEME project. The light on the street it's directly driven by the actual traffic volume.
Figure 21 can quickly demonstrate how such a strategy can be highly convenient than the full light and pre-programmed approach.
The consortium evaluates the energy-saving provided by all the lighting points driven by the adaptive lighting methods installed along Roma streets.
In Rome, the consortium installed a total of 796 lighting points. 108 lighting points refers to the Small test Site.
We equipped the Large test site with a total of 688 LIFE-DIADEME devices. 614 in the EUR area and 74 along Pietralata district.
We considered, for the evaluation, a total of 365 days, from 31 October 2019 to 31 October 2020.
As previously mentioned, the consortium progressively activated the adaptive lighting along with the Roma large test site with different timing.
Activities started in early October 2019 and finished in March 2020.
For the final energy-saving evaluation, we used the data gathered from each lighting point, working with the adaptive lighting method.
In Rome, the lighting points usually works at full power. The full-power strategy is the normal condition even for the lighting points involved with the LIFE-DIADEME project. The single lighting point provided Roma streets with full light until the programming for an adaptive lighting strategy.
It's important to underline this approach because, for the one-year evaluation, if a lighting point wasn't working in an energy-saving mode, it contributes to the final value with full-power data.

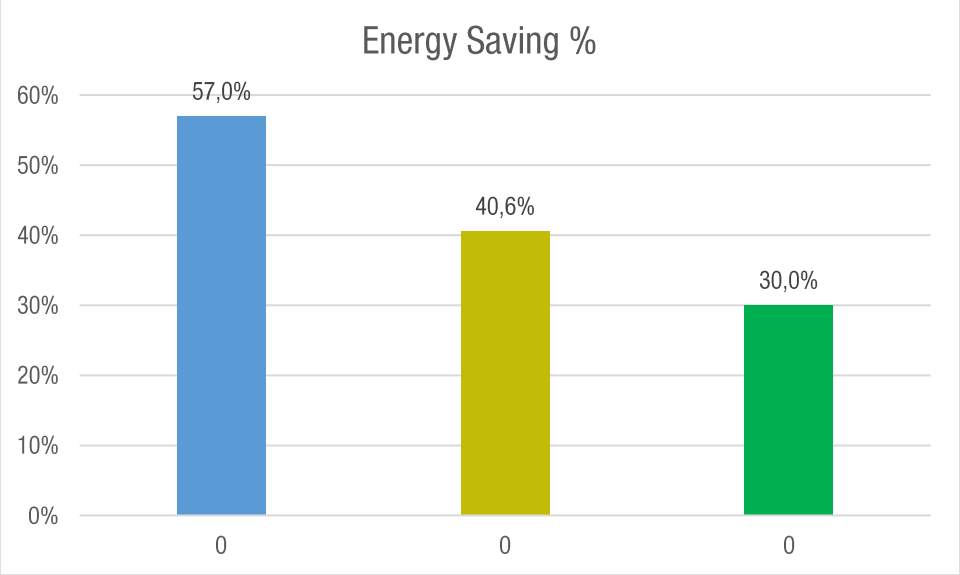
The final energy-saving results, potentially, can be more significant. If the evaluation is performed in one year with all the lighting points fully working with adaptive lighting, final savings probably will be more impressive.

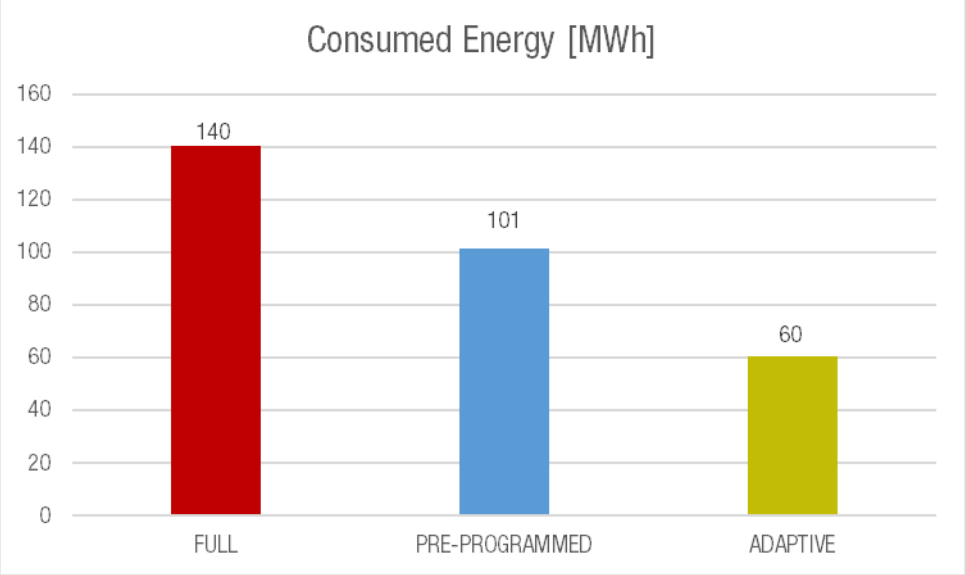
Roma LIFE-DIADEME Large test site performed better than the 30% energy savings project target.
The LIFE-DIADEME adaptive system, compared with the pre-regulated strategy, provided an energy savings of 40.6% over the one-year test period.
Compared to the full-light strategy, results along the same period provided an energy savings of 57.0%.

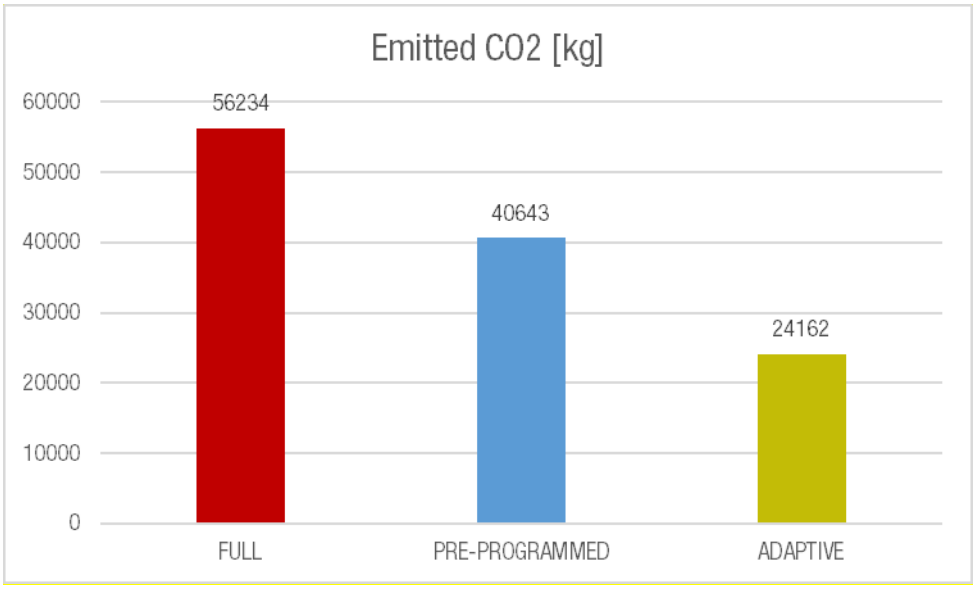
Results confirmed that an adaptive system lighting plant could provide significant energy saving, considerable GHG emission and a lower production cost for street lighting functionality.

	Consumed Energy [MWh]	Emitted CO2 [kg]
FULL LIGHT	140,397	56234
PRE-PROGRAMMED	101,472	40643
ADAPTIVE	60,325	24162

	Energy Saving %	Saved Energy [MWh]	Saved CO2 [kg]
VS FULL	57,00%	80,1	32072
VS PRE-PROGRAMMED	40,60%	41.1	16481
PROJECT TARGET VS PRE-PROGRAMMED	30,00%	30.4	12193






Emitted CO2 [kg]
60000
50000
40000
30000
20000
10000
0
56234
40643
24162
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 conditionsThe system used data acquired both by LIFE-DIADEME devices and LTM cameras to drive street lighting levels according to UNI11248 Technical standards.
Due to the different streets and data related to the Roma Large test site, we decided to focus on a few valuables roads as a sample for the Rome Large test site traffic.
We have chosen three roads for the EUR Large Test site and one road for the Pietralata site. For the EUR zone, the selection was to expose data of Rome's main road, Via Cristoforo Colombo. Of interest, there is another large road, Viale dell'Oceano Atlantico; a road with a good traffic level but with a small volume if compared with Via Cristoforo Colombo. On the other side of EUR, Via dell'Agricoltura: it's a road mainly used by workers to enter the Roma EUR office zone. This is a small street with an accent on working traffic.
In a completely different zone of Rome, there is the Pietralata district. The selected plant it's inside a residential zone with schools, a hospital and a swimming pool. A completely distinct environment if compared with the Roma EUR situation.
The following one-year analysis enables a comparison between regular days and pandemic days. We will evaluate two completely different periods to understand how smart city data traffic as the LIFE-DIADEME system can support the decision-maker when necessary real-time traffic monitoring.

Figure 21 Traffic Example Plants - Roma EUR

Figure 22 Traffic Example Plant+ - Roma Pietralata

Roma EUR – Via Cristoforo Colombo

Via Cristoforo Colombo, it's one of the most crucial roads of Rome. It connects the sea to the centre of Rome. The length of this direct access to the city makes this road an intense traffic volume street.

The Roma EUR zone of Via Cristoforo Colombo it's organised as a three lanes double carriageway road.

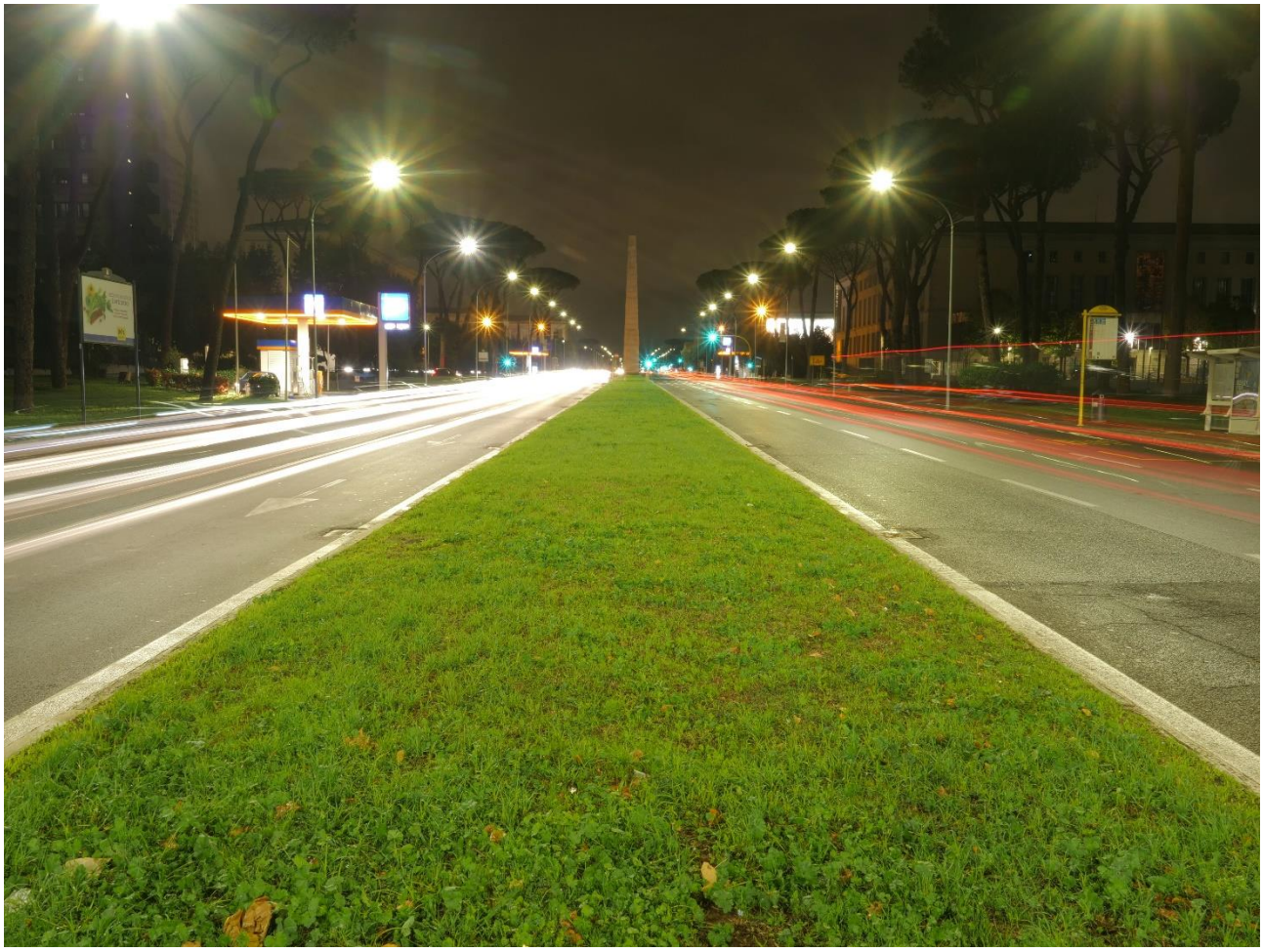


Figure 23 Roma EUR Via Cristoforo Colombo

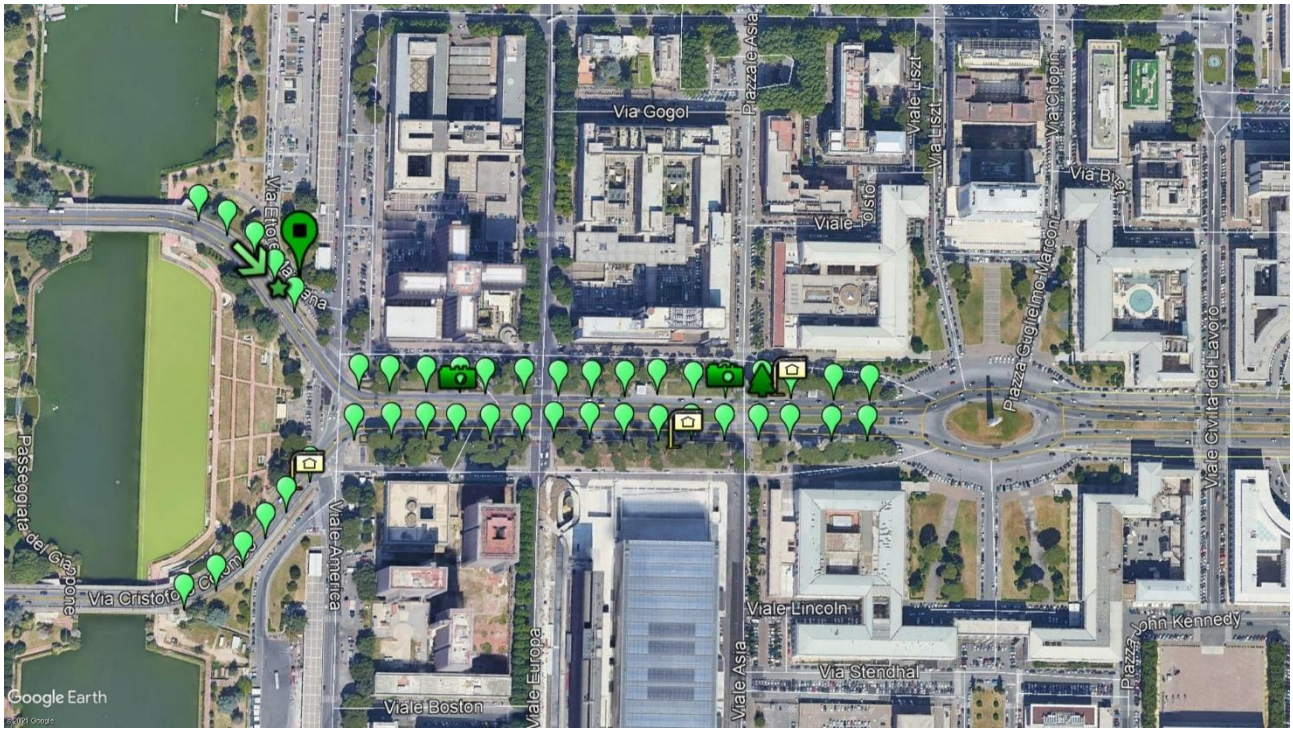


Figure 24 Via Cristoforo Colombo Test Site

In Figure 25, we can observe a graph where's reported the traffic volume along Via Cristoforo Colombo from 20 November 2019 to 31 December 2020.
It is more than one year monitoring period, and the picture exposes different traffic volume behaviours, especially in a strange year like 2020.
As we can see, the standard traffic for Via Cristoforo Colombo it's near 2000 vehicles per hour per lane. Via Cristoforo Colombo's carriageway enables a traffic volume near 6000 vehicles/hour in a conventional period. More or less, 100 Vehicles every minute.
We had the opportunity to evaluate the pandemic period and the results of lockdown restrictions.
In the middle of the following picture, we can note a strange reduction in traffic volume. This reduction's the effect of the lockdown for the pandemic COVID-19 in March and April 2020.
We can observe, on the left of the picture, a standard time where traffic was heavy. As we said previously, Via Cristoforo Colombo is one of the direct access to Rome's centre and, in normal conditions, traffic is always severe. In the lockdown period, the traffic volume drastically collapsed. The data collected by the LIFE-DIADEME system are helpful to provide objective evidence about what Romans have experienced during the 2020 pandemic lockdown. It was a two months period where traffic was abnormally low, and this can be numerically observed.
From May 2020, the Italian government slightly reduced the lockdown measures. As consequence, traffic started increasing. The traffic seems to return to a natural level during summer 2020, with a slight reduction in August's central period. If we think about the Italian summer holidays, the explanation about traffic reduction it's easy. Unfortunately, after a quiet time, the covid pandemic hit once again the Italian drivers. We can observe how fragmented it's the measured traffic volume during the last months of 2020. Not comparable with the same period of 2019 (on the left of the picture). In the later part of the year, the Italian government imposed a Christmas Covid 19 Pandemic lockdown, and this period was observable on the extreme right part of the graph.

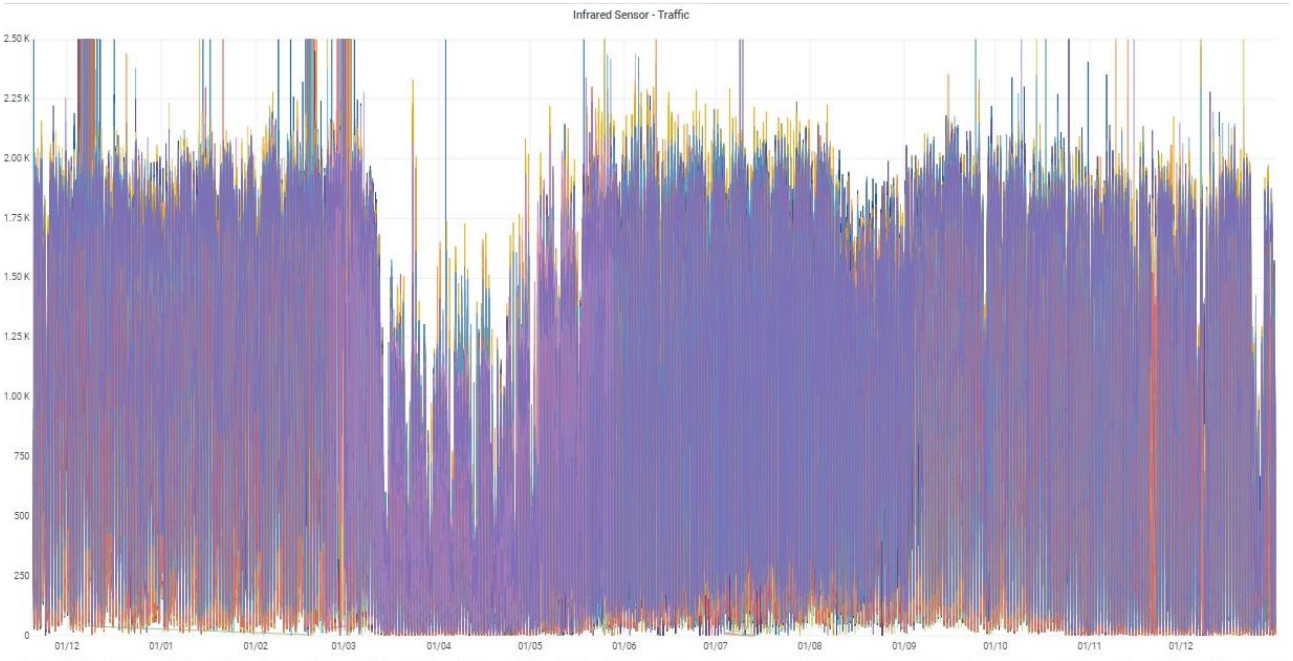


Figure 25 Roma Eur Via Cristoforo Colombo - 20 November 2019 - 31 December 2020

In Figure 26, we focus the attention on the lockdown time of march and April 2020. We can observe how the traffic was consistently lower in this period compared with the usual previous weeks. Looking at the data, we can have the evidence of the weekend.

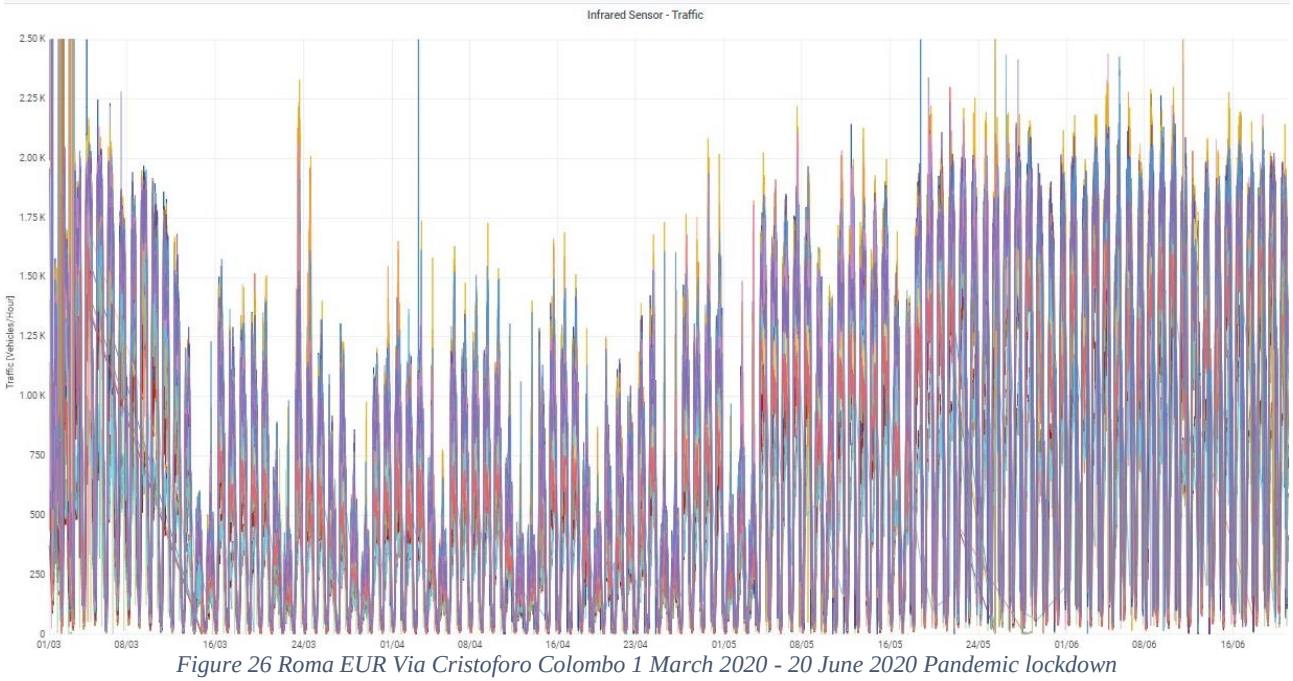


Figure 26 Roma EUR Via Cristoforo Colombo 1 March 2020 - 20 June 2020 Pandemic lockdown

Roma EUR – Viale dell'Oceano Atlantico

Viale dell'Oceano Atlantico it's a wide street of the Roma EUR district. People uses Viale dell'Oceano Atlantico to reach the Roma EUR's east side without using Viale Cristoforo

Colombo. This road's also strategic because it rapidly connects Via Cristoforo Colombo with Via Laurentina, another main street to enter or go out from Rome. Near this road, there is a big mall and seldom, traffic along this street it's complicated by all the customers going shopping. Viale dell'Oceano Atlantico is a dual lane double carriageway street.

Figure 27 Roma EUR Viale dell'Oceano Pacifico

Figure 28 Viale dell'Oceano Atlantico Test Site

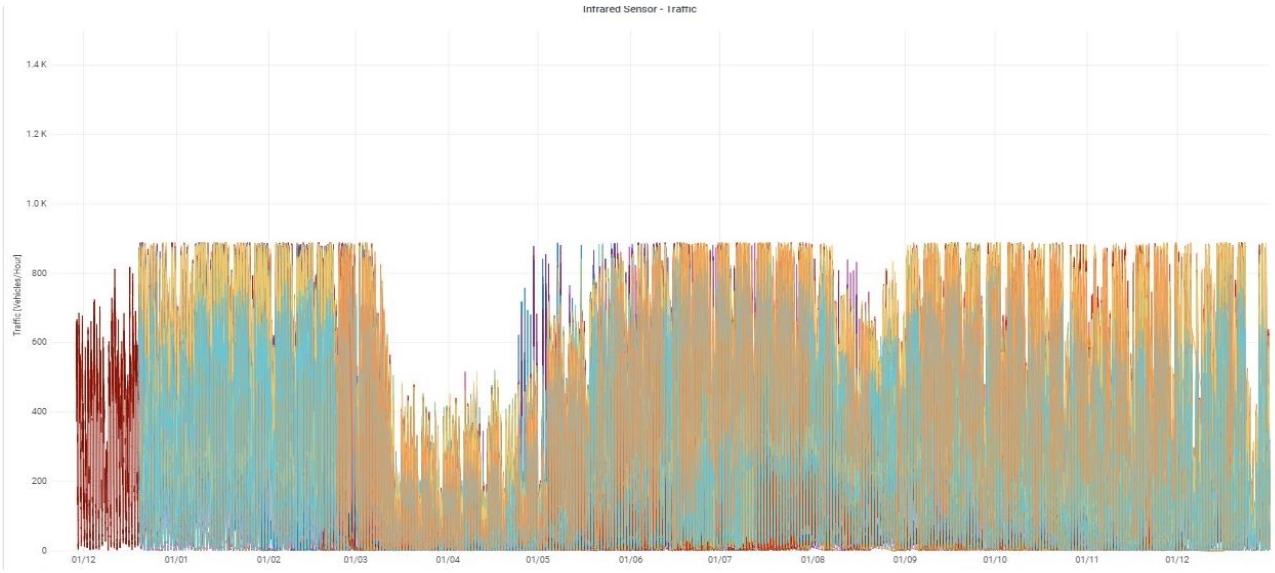


Figure 29 Figure 30 Roma Vial Dell'Oceanto Atlantico - 1 December 2019 - 31 December 2020

In Figure 29, we can observe a graph where's reported the traffic volume along Viale dell'Oceano Atlantico from 1 December 2019 to 31 December 2020.
It is more than one year monitoring period, and the picture exposes different traffic volume behaviours in the pandemic year 2020.
As we can see, the standard peak traffic for Viale dell'Oceno Atlantico it's near 900 vehicles per hour per lane, a level utterly different if compared with Via Cristoforo Colombo, where the measured traffic volume peak value it's near 2000 vehicles per hour per lane. Via Cristoforo Colombo's carriageway enables a traffic volume near 6000 vehicles/hour in a conventional period. More or less, 100 Vehicles every minute. Viale dell'Oceano Atlantico, really a smaller value: this is a double carriageway double lanes road. The detected value confirmed the idea about Viale Dell'Oceano Atlantico; it is a road in the south perimeter of the Roma EUR district. The traffic volume is significant but nothing compared with a primary road as Via Cristoforo Colombo. The peak volume of traffic and Viale dell'Oceano Atlantico are about 30 vehicles per minute in each direction.
Thanks to the long monitoring period and the gathered data, we had the opportunity to evaluate the pandemic period and the results of lockdown restrictions.
In the middle of Figure 29, we can note a reduction in traffic volume. This reduction's the effect of the lockdown for the pandemic COVID-19 in March and April 2020. As for Via Cristoforo Colombo, we can observe a standard time where traffic was heavy (on the left of the picture). In the lockdown period, the traffic volume drastically collapses. The data collected by the LIFE-DIADEME system are helpful to provide objective evidence about what Romans have experienced during the 2020 pandemic lockdown. It was a two months period where traffic was abnormally low, and this can be numerically observed. From May 2020, the Italian government slightly reduced the lockdown measures. As consequence, traffic started increasing. The traffic seems to return to a natural level during summer 2020, with a slight reduction in August's central period. If we think about the Italian summer holidays, the explanation about traffic reduction it's easy. Unfortunately, after a quiet time, the covid pandemic was once again on the Italian territory.
We can observe how fragmented it's the measured traffic volume during the last months of 2020. Not comparable with the same period of 2019 (on the left of the picture). In the later part of the year, the Italian government imposed a Christmas Covid 19 Pandemic lockdown, and this period was observable on the extreme right part of the graph. The previous considerations are the same as for Via Cristoforo Colombo. As exposed for two different traffic roads, the

numerical evidence instead of sensations provide the municipality with tangible proof about citizen behaviours in such a dramatic time.

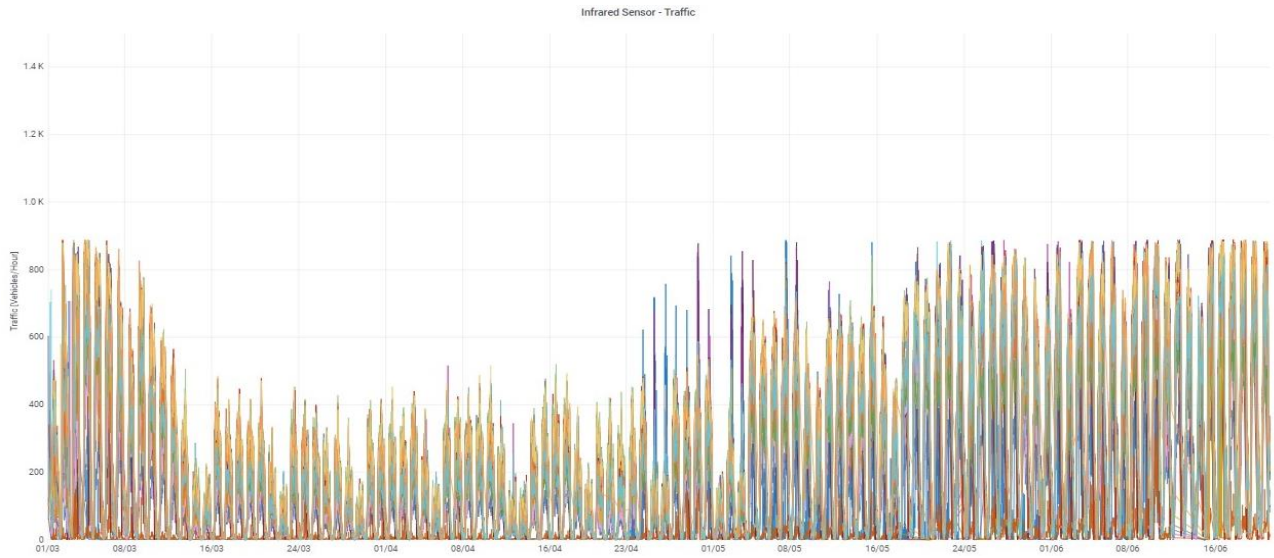


Figure 31 Roma EUR Viale dell'Oceano Atlantico 1 March 2020 - 20 June 2020 Pandemic lockdown

In Figure 31, we focus the attention on the lockdown time of March and April 2020. We can observe how the traffic was consistently lower in this period compared with the usual previous weeks. Looking at the data, as for Cristoforo Colombo, we can have the evidence of the weekend, when the traffic volume was further reduced compared to a working day.

Roma EUR – Via dell'Agricoltura

Via dell'Agricoltura it's a small road in the centre of the Roma EUR district. This street connects the office zone with the external and more trafficked roads. Workers and citizens mainly use it to arrive in the area near "Palazzo della cività Italiana". It's not a high volume traffic road, but there are topic moments when traffic becomes intense. Via dell'Agricoltura, it's a single carriageway, dual lanes road.

Figure 32 Roma EUR Via dell'Agrcoltura

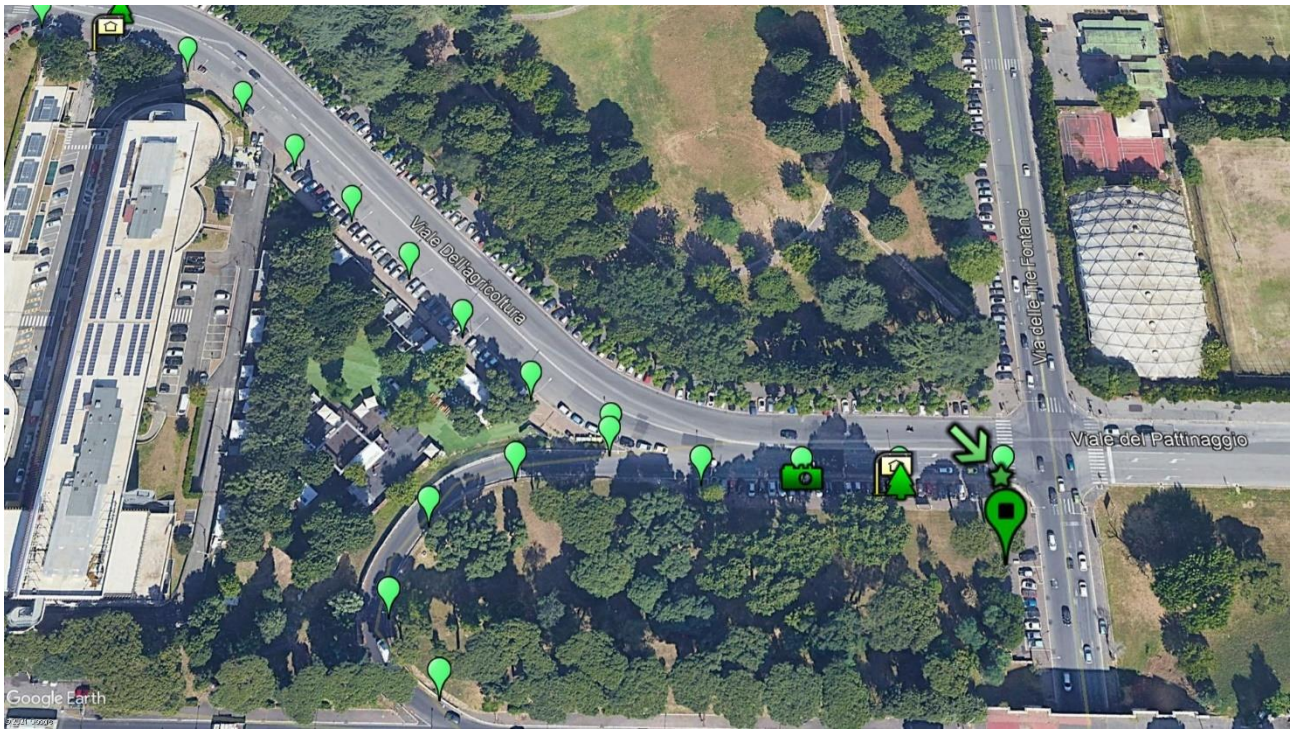


Figure 33 Viale dell'Agricoltura Test Site

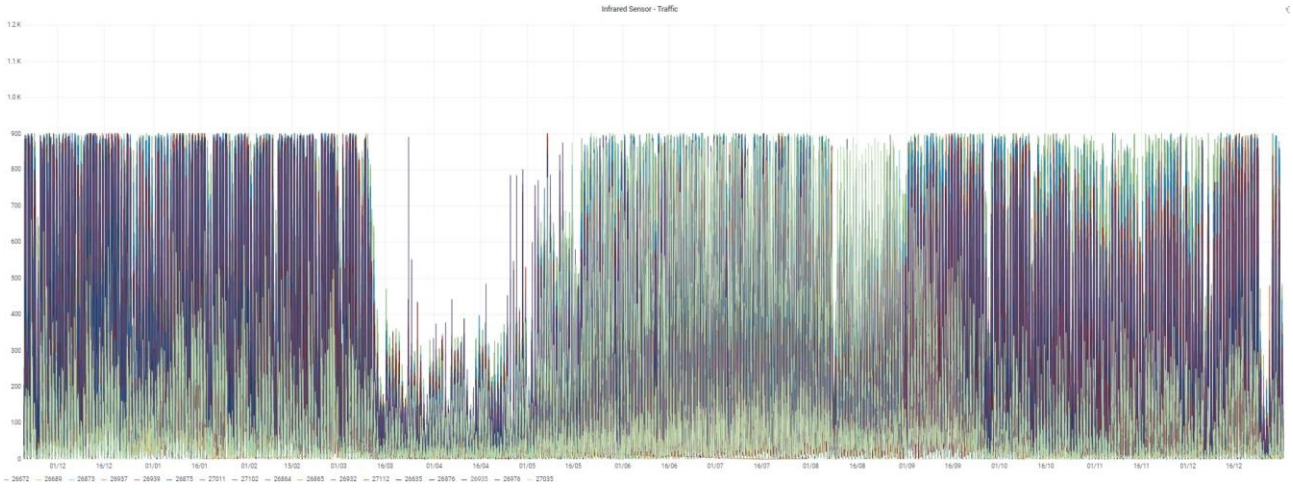


Figure 34 Roma Eur Via dell'Agricolutra - 20 November 2019 - 31 December 2020

In Figure 34, we can observe a graph where's reported the traffic volume along Via dell'Agricoltura down the period from 20 November 2019 to 31 December 2020.
It is more than one year of monitoring time, and the picture exposes different traffic volume behaviours in the pandemic year 2020.
As we can see, the standard peak traffic for Via dell'Agricoltura it's near 900 vehicles per hour per lane, a level utterly different if compared with Via Cristoforo Colombo, where the measured traffic volume peak value it's near 2000 vehicles per hour per lane. This traffic volume it's comparable with the level detected along with Viale dell'Oceano Atlantico. And this information it's pretty surprising. This road is an access road for the EUR district's centre from the consortium point of view. It's not crucial as Via Cristoforo Colombo. However, the LIFE-DIADEME system's provided information makes it numerically obvious that Via dell'Agricoltura is a well known and valuable way to enter the Roma EUR office zone directly. Via Cristoforo Colombo's carriageway enables a traffic volume near 6000 vehicles/hour in a conventional period. More or less, 100 Vehicles every minute. Viale dell'Oceano Atlantico, a double carriageway double lanes road, about 30 vehicles per minute in each direction. 30 cars per minute are the same traffic volume detect along Via dell'Agricoltura, a single carriageway dual lane road. Lanes on via dell'Agricoltura are huge. The drivers probably use the single lane as a double lane, significantly increasing the road traffic capability.
The consideration of the clever use of a single large lane as a double lane was possible using the data collected by the LIFE-DIADEME system. There is evidence that the traffic volume it's consistently higher if compared to expected values. And this is numerically assessed by an automatic detection system.
Thanks to the long monitoring period and the gathered data, we had the opportunity to evaluate the pandemic period and the results of lockdown restrictions even along this road. As we have previously seen, in the middle of Figure 34, we can note a reduction in traffic volume. This cut's the effect of the lockdown for the pandemic COVID-19 in March and April 2020. As for Via Cristoforo Colombo and Viale dell'Oceano Atlantico, we can observe a standard time where traffic was heavy (on the left of the picture). In the lockdown period, the traffic volume drastically collapses. The data collected by the LIFE-DIADEME system are helpful to provide objective evidence about what Romans have experienced during the 2020 pandemic lockdown. It was a two-month period where traffic was abnormally low, which can be, finally, numerically observed. From May 2020, the Italian government slightly reduced the lockdown measures. As consequence, traffic started increasing. The traffic seems to return to a natural level during summer 2020, with a slight reduction in August's central period. If we

think about the Italian summer holidays, the explanation about traffic reduction it's easy. Unfortunately, after a quiet time, the covid pandemic was once again the Italian and Roman's citizens' immediate priority.
We can observe how fragmented it's the measured traffic volume during the last months of 2020. Not comparable with the same period of 2019 (on the left of the picture). In the later part of the year, the Italian government imposed a Christmas Covid 19 Pandemic lockdown, and this period was observable on the extreme right part of the graph. The previous considerations are the same as for Via Cristoforo Colombo. As exposed for two different traffic roads, the numerical evidence instead of sensations provide the municipality with tangible proof about citizen behaviours in such a drammatic time.

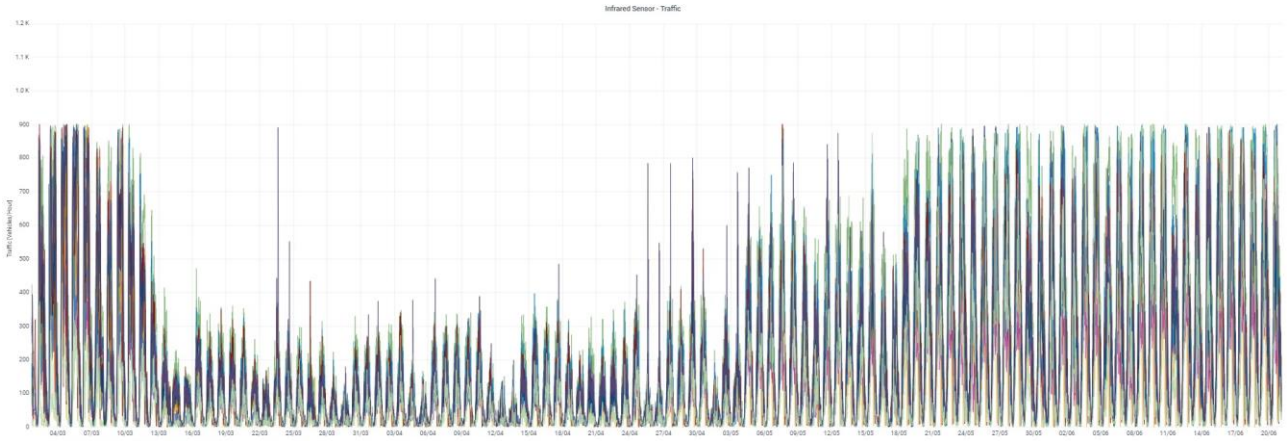


Figure 35 Via Dell'Agricoltura 1 March 2020 - 20 June 2020 Pandemic lockdown

In Figure 35, we focus the attention on the lockdown time of March and April 2020. We can observe how the traffic was consistently lower in this period compared with the usual previous weeks. Looking at the data, as for Cristoforo Colombo and Viale dell'Oceano Atlantico, the trend it's completely similar. Once again, sensations about reduced traffic volume are measured and exposed by numbers. Data can drive considerations about traffic during the Covid19 pandemic lockdown.

Roma Pietralata – Via Achille Zigno

From the consortium point of view, the more noticeable road along the Pietralata site is Via Achille Zigno; it is a straight road in a residential zone that serves a well known swimming pool and a school district. The traffic usually's very low with some peaks during scholastic entering and going out. Via Achille de Zigno, it's a dual lane, single carriageway road.
ROMA CAPITALE required this installation to test the system in a condition entirely different from the EUR District. It's of consortium interest to evaluate how the system worked in a district that it's more urbanised and mainly dedicated to citizens.

Figure 36 Roma Pietralata - Via Achille De Zigno

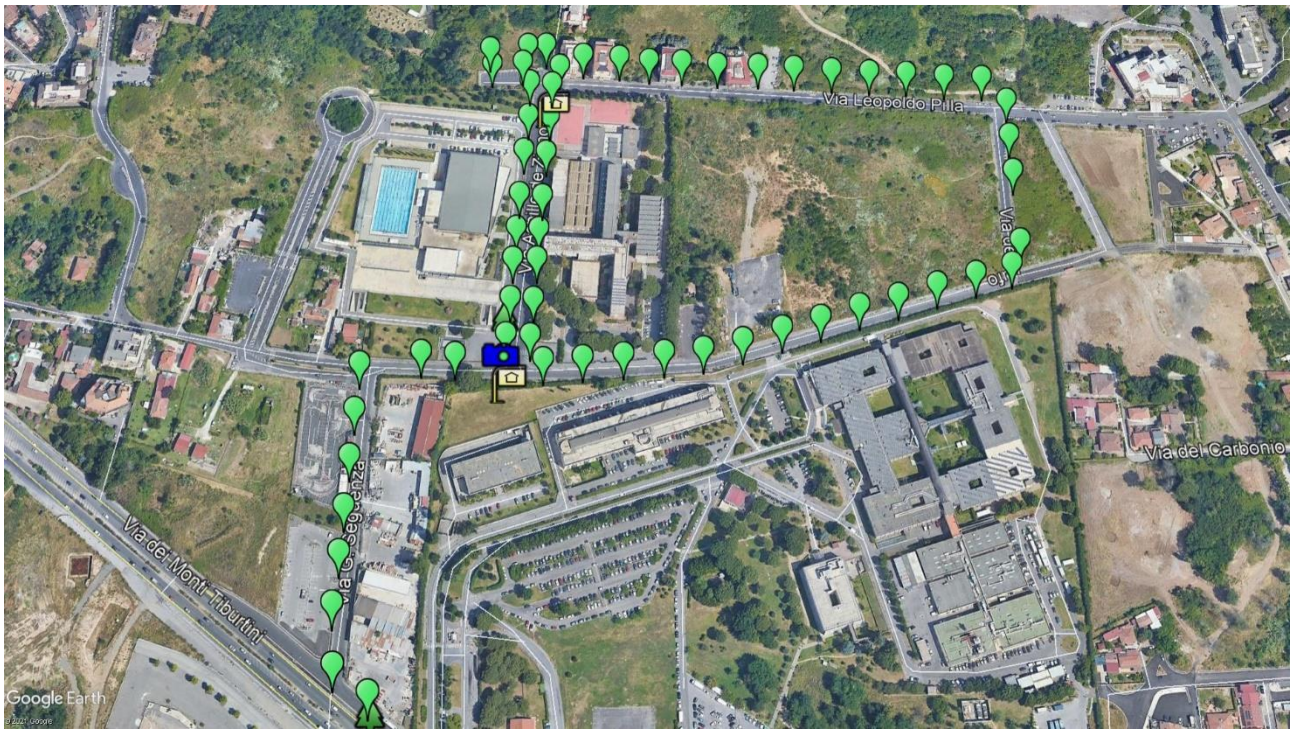


Figure 37 Pietralata Test Site Zone

Pietralata test site was the last installation along with the Roma Large Test Site. The consortium installed devices in February 2020, and data from this plant are available from 20 February 2020.

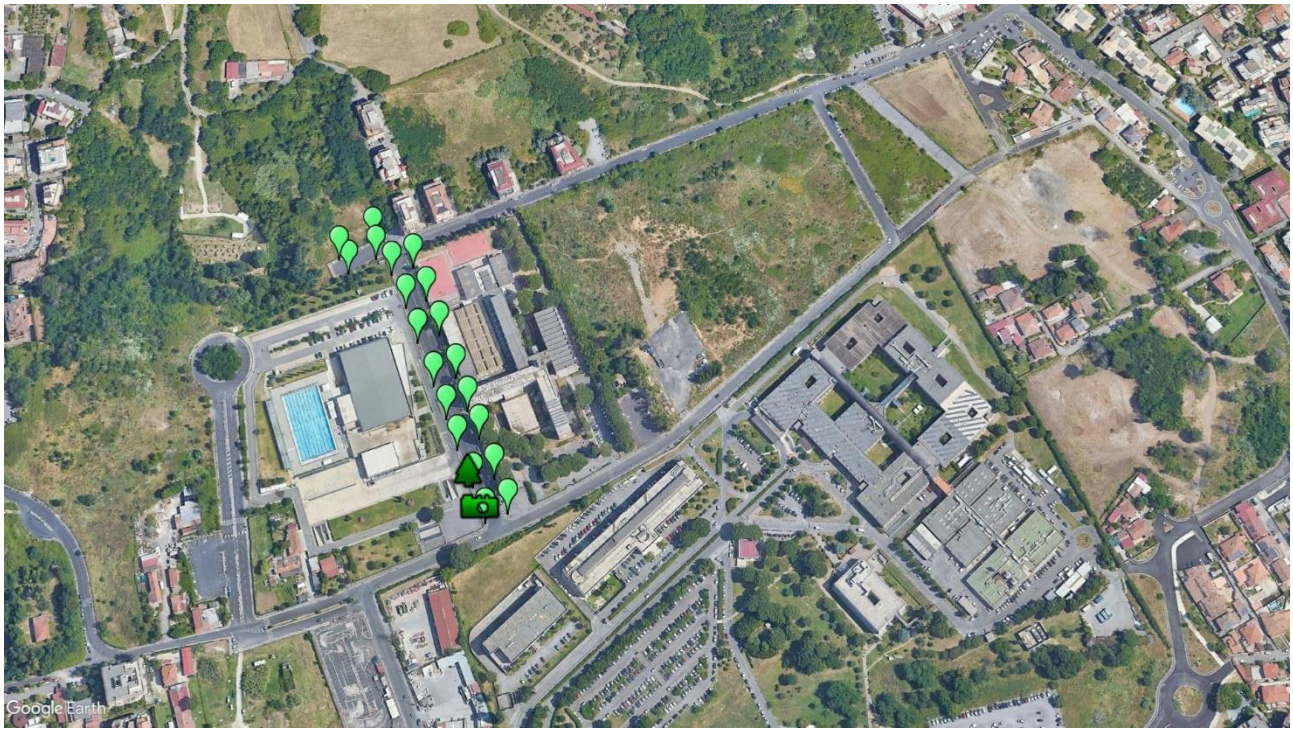


Figure 38 Via Achille De Zigno

For the Pietralata test site, we focus the report attention on Via Achille De Zigno. In Figure 38, the details about LIFE-DIADEME system plant installation.
We selected this road because it's of particular interest. This part of Pietralata it's a district residential zone, but, specifically along with Via Achille De Zigno, we can find two points of interest for the community: a high school and an Olimpic swimming pool (Figure 39).

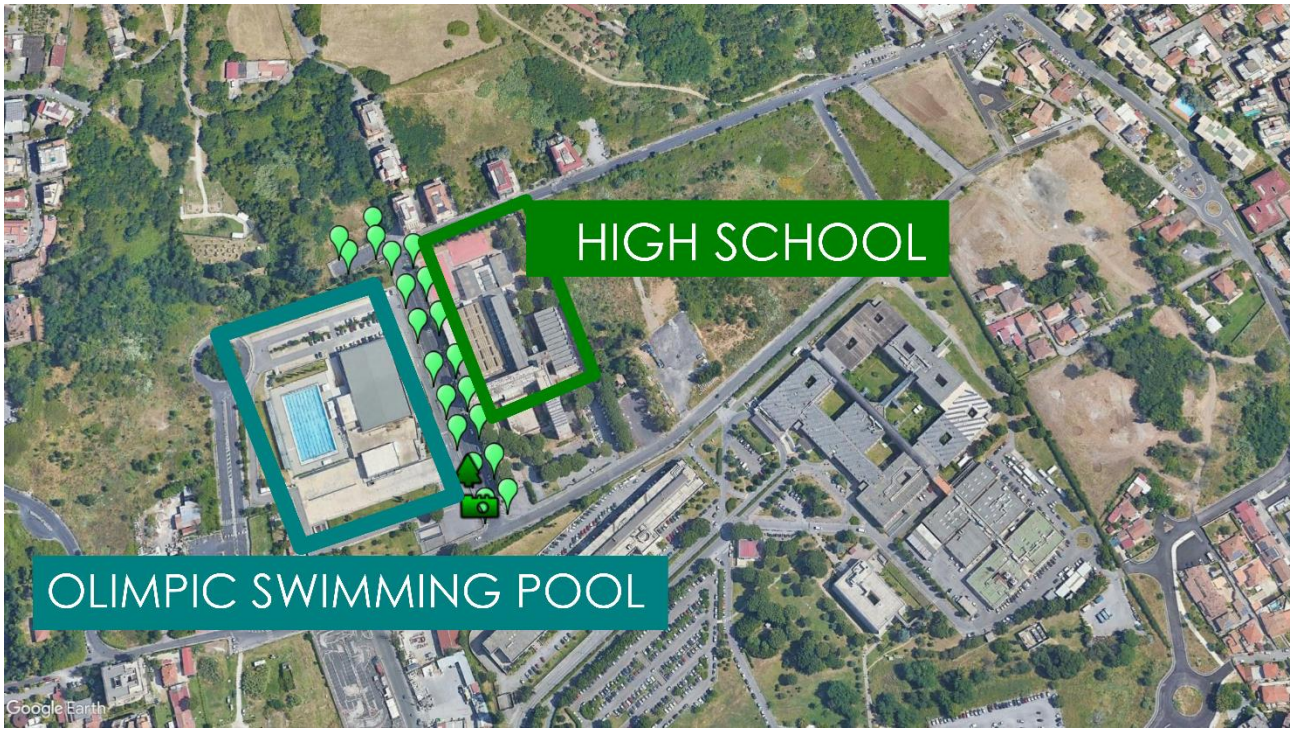


Figure 39 Pietralata - Via Achille De Zigno - Points of interest

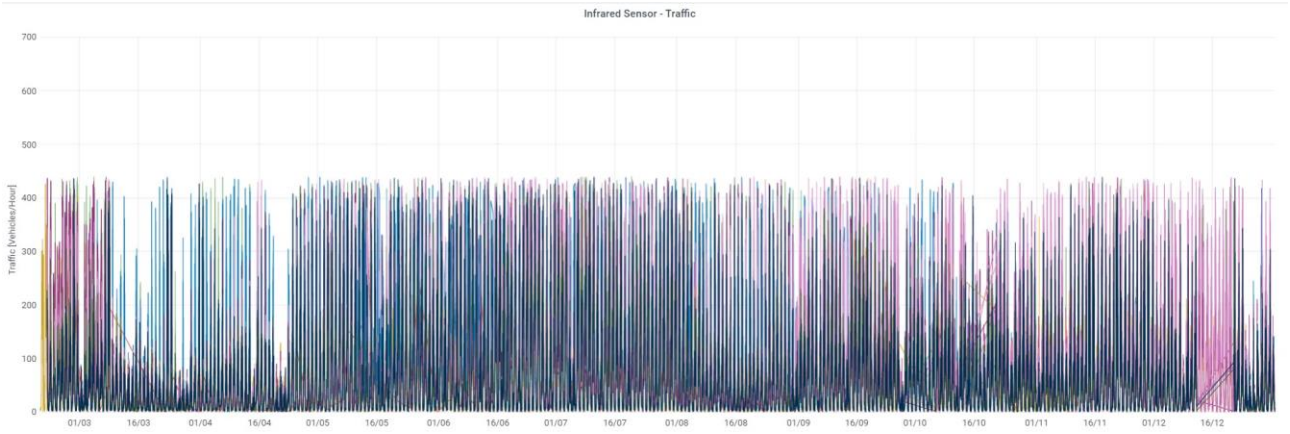


Figure 40 Pietralata Via Achille De Zigno - 20 February 2020 - 31 December 2020

In Figure 40, we can observe a graph showing the traffic volume along Via Achille De Zigno down the period from 20 February 2020 to 31 December 2020.
If compared to the other analysed test site, up to the end of 2020, for the Pietralata test site, the consortium collected less than one year of information. Nevertheless, as we can see in the following evaluations, from the collected data, we can find interesting information.
The first consideration of the traffic and Achille De Zigno is about the maximum traffic volume detected. The detected peak it's more or less 400 vehicles/hour, half of the less trafficked road along with Roma EUR. This consideration's helpful to evaluate the LIFE-DIADEME traffic monitoring capability even in a low traffic zone.
Another consideration we can achieve from the previous picture it's about the peaks density: on the other test site, the peaks were really near one to each other. For this road, it's not like that. The traffic's substantially seems less intense.
It's also interesting the evaluation of the lockdown time during March and April 2020. If the situation was evident in the other conditions, we can't say the same things about Via Achille De Zigno. We can note a reduction in traffic volume, but something seems different. We will analyse this behaviour next.
Starting from August 2020, the traffic volume along Via Achille De Zigno seems consistently reduced, and it never reached the values detected in June and July.

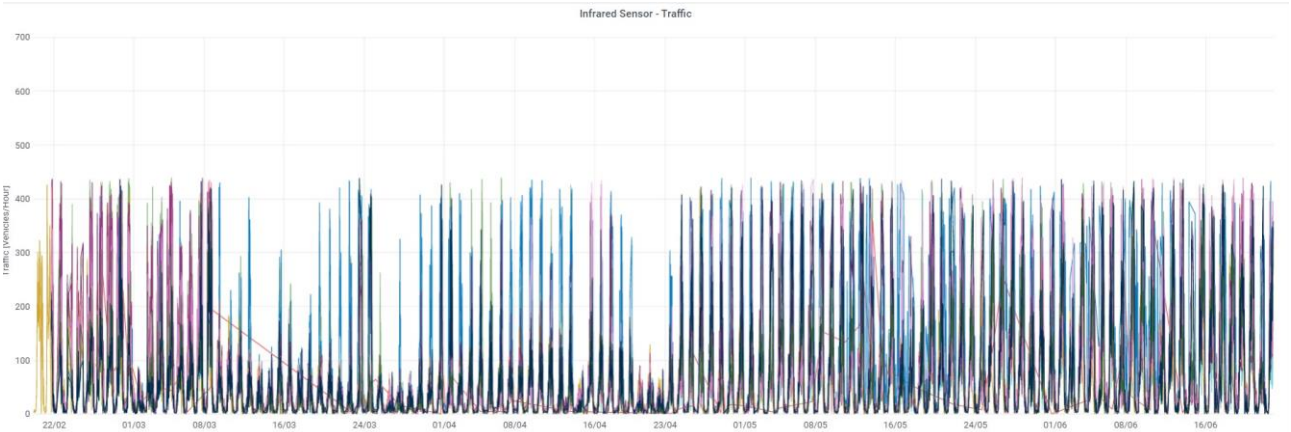


Figure 41 Via Achille De Zigno March 2020 - 20 June 2020 Pandemic lockdown

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, provides supervision for human safety and environmental conditions.

Every single device provides for a continuous noise sampling of two different audio parameters: noise and background levels (LApk and LA95)
Starting from LApk and LA95, complex technical data, the LIFE-DIADEME system evaluates a parameter easy to understand by citizens: the Harmonica Index.
Harmonica Index it'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 non-specialists 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 type of period (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.

The consortium equipped all the lighting points along with the Roma test site with environmental noise capabilities.

The installation delay on Piacenza and Rimini test site allowed the consortium better to adjust electronics on the board of the LIFE-DIADEME systems, providing other helpful information for final system validation. About in field measurements, the consortium wasn't able to evaluate with a calibrated system the values detected by the system along Via Achille De Zigno. The reason was the Covid19 Pandemic. Roma and the Pietralata test site, for the test team, along 2020 become a problematic destination, and we decide to concentrate energies on the other two test sites. Reverberi personnel performed audiometric detection in Rimini and Piacenza for a day, without an overnight stay. Please refer to Rimini and Piacenza test site report to analyse the noise measurement systems and measured performances.
From the Piacenza and Rimini test site experience, we can assimilate the Roma test site's geometrical installation to the Piacenza one. For this reason, the consortium expects that data collected by the Pietralata systems are as consistent and valuable as the one detected in Piacenza.


Roma


Piacenza


Rimini

Figure 42 Installation comparison between test sites

AIR QUALITY DETECTION

Air Quality Installation

For the LIFE-DIADEME Roma test site, the consortium installed 39 air quality detection units, 35 in the EUR zone and the other 4 in the Pietralata district.
Thanks to the collaboration with ARPA Lazio, the consortium had the opportunity to install one detection unit directly above an ARPA cabinet in the Pietralata zone. The ARPA system is far from the specific air quality systems installed in Pietralata, but ARPA Lazio's collaboration provides exciting results.
Figure 43 and Figure 44 represents all the low-cost air quality systems installed along with the Large test site.

Figure 43 LIFE-DIADEME ROMA EUR Air Quality Installation

Figure 44 LIFE-DIADEME ROMA PIETRALATA Air Quality Installation

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 the Roma Small Test Site air quality devices, the consortium prepared the later systems (Roma Tiburtina, Rimini and Piacenza devices) differently.
Before the delivery to Rome, Reverberi changed some electronics settings and performed a single system calibration.
In Rome, the consortium installed only one low-cost sensor precisely calibrated on the Tiburtina ARPA cabinet board.
Thanks to the collaboration with ARPA Lazio, the low-cost unit, after an initial calibration in the Reverberi factory, was also tested in ARPA Lazio laboratories.
The unit was assessed with different gas and different concentration levels to understand low-cost sensor effectiveness.
In October 2020, the consortium and ARPA Lazio installed low-cost unit on the roof cabinet of the Tiburtina ARPA unit.
The consortium and ARPA Lazio performed the test on data collected from 8 January 2021 to 18 February 2021.

Air Quality Detection Results

Compared with ARPA Lazio reference values, low-cost data along with Via Tiburtina 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 20%. The NO sensor, which seems the best performer in other installation, Via Tiburtina, exposed some overshoots on gas peaks concentration, influencing the final results.
On the other side, the NO2 sensor gave interesting results.
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 Rome provided better energy and GHG savings results if compared with the project targets.

The adaptive system performed a 40.6% energy saving in the monitored period, going beyond the 30% fixed project target.
Compared to Rome's standard full light strategy, the LIFE-DIADEME exploited an astonishing 57% energy savings along with the test site plants.
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 Roma test site was able to exploit real-time traffic condition counting, collecting valuable information about traffic volume along all the monitored roads.
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 Roma fully achieved all the project targets.