APPRAISAL REPORT

FOR DUBROVNIK PORT AUTHORITY PILOT ACTION

Project acronym	ADRIGREEN
Project Title	Green and intermodal solutions for Ports and Airports
Financed through	ERDF
Project duration	01/01/2019 – 31/12/2021

Related activity:	4.1 –Testing phase
Deliverable name:	Appraisal report for Dubrovnik Port Authority pilot action
Type of deliverable	Report
Language	English
Work Package Title	Testing and evaluating innovative intermodal and low-carbon solutions
WP number	4
WP Coordinator	Dubrovnik Airport

Status	Final
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Version	1
Due date of deliverable	31st August 2021
First draft:	31st July 2021
Final delivery date	14st August 2021
Project website	https://www.italy-croatia.eu/web/adrigreen

CONTENT

I. EXECUTIVE SUMMARY

According to application form of ADRIGREEN project, partners should implement its pilot action covering one of the four main pilot action goals identified:

➢ implementation of low-costs and smart solutions to better connect airports and ports with local public transportation system, such us railways and public bus lines;

➢ implementation of integrated timetabling and information for passengers that must continue their travel by other means of transportation;

➢ adoption of smart solutions to improve waste and water management and to reduce energy consumption in small-medium regional Airports;

➢ new protocols with public and private transportation providers to experiment new services to speed up the process of passengers from/to touristic destinations which are not well-connected.

Main deliverables of pilot action implementation should be Feasibility study of implemented action as well as testing report of implemented action, which will be basis for further project steps, especially in conducting Capitalisation manual on identified and tested solutions within ADRIGREEN projects.

Therefore, this document should evaluate pilot action implemented with clear conclusion regarding its feasibility and transferability to other regions or airports, contributing to project transnational approach conclusion which shall be summarized in Capitalisation manual.

The aim of this Feasibility Study (deliverable 4.1.) is to outline the reasons underpinning the pilot action choice, its benefits and the internal monitoring mechanism to ensure the efficient realisation of actions' output.

In addition, this document will underline the feasibility and transferability of the pilot action, contributing to project transnational approach.

Testing results of implemented pilot action in Dubrovnik Port Authority have demonstrated its advantages from process optimization point of view as well as from feasibility (cost-effectiveness) and environmental perspective.

In addition, Dubrovnik Port Authority has presented pilot action implementation plan covering all implementation process phases, from appointing project team, through identifying risks and risk mitigation procedures, conducting public procurement process and, in the end, implementation of equipment and monitoring of its performance.

Conclusion from this study represents recommendations to Dubrovnik Port Authority management board as well as to other interested parties on how benefits from green field process thinking and optimization may contribute to the organization.

Also, to have adequate knowledge on impact and in order to ensure durability of similar pilot actions implemented, it is essential that company implements environmental management system process in place, as an integrated tool for planning, implementation and monitoring of environmentally friendly activities.

II. BACKGROUND OF THE PROJECT IMPLEMENTATION

Green and intermodal solutions for Adriatic ports and airports - ADRIGREEN is a project approved under the INTERREG V-A Italy Croatia CBC Programme 2014- 2020. The programme is funded by the European Regional Development Fund under the European Territorial Cooperation objective during the programming period 2014- 2020.

The managing body of the Cooperation Program is the Veneto Region, Italy. The national body of the Republic of Croatia coordinating the implementation of the joint programme with other participating countries is the Ministry of Regional Development and European Union funds.

The project has started in January 2019 and it is expected to end by January 2022. The total budget approved for the project amounts to 2.104.217,00 EUR, 85% of which is co-financed through the ERDF fund (European Regional Development Fund). The project is implemented by 10 project partners (Pula Airport Ltd., Dubrovnik Airport Ltd, Airports of Apulia S.P.A., Airiminum 2014 S.P.A., Abruzzo Airport Management Company Ltd., Dubrovnik Port Authority, Central Adriatic Ports Authority, Pula Port Authority, *Southern Adriatic Sea Port Authority*, University Polytechnic of Marche). The lead Partner is Pula Airport Ltd.

Project description

The main objective of ADRIGREEN project is to improve the integration of Croatian and Italian ports and airports with other modes of transportation in order to enhance the processing of passengers during the summer seasons and to improve environmental performances of the Adriatic maritime and aviation systems. To do that, the project will implement a set of structured activities based on transnational and cooperative approach.

One of the main problems that characterize the Adriatic coastal area is the imbalance in the development of infrastructures and modes of transport, caused by low level of investments and insufficient approach to innovation. In Italy and Croatia there are many maritime cities, which have to deal with a very high number of passengers, especially during the peak season. Even though the road transportation is still predominant, the number of people that are reaching Adriatic cities by ferries and airplanes is significantly increasing year by year.

However, most of Adriatic ports and airports are suffering from lack of integration with various modes of transportation, causing serious traffic congestion problems during the summer season.

The main idea is to identify and analyse a few existing operational and technological solutions that can be easily transferred and adapted by involved ports and airports. The partners are not interested in inventing new solutions as there are a plenty successful models and schemes implemented in other parts of the world that can be replicable also in the Programme area. Once the solutions have been identified and

analyses, the project partner will test the operational and technological models on their facilities so as to improve intermodal connections and to put in practices new schemes for a sustainable management of ports and airports. The objective of the testing phase will be to demonstrate the feasibility, the effectiveness, and the replicability of the identified solutions. Finally, intention of the project is to disseminate the results of tested solutions so as to explain also to other ports and airports how the operational procedures and technological innovation can be successfully transferred and used.

Also, it is very important to create more environmental-friendly and less polluting transport between ports (cities) and airports by reducing CO2 emissions. This can be achieved by purchasing electric vehicles for transport routes between ports and airports, or for use in port/airport premises.

Background of project implementation

ADRIGREEN project consists of several technical work packages as follows:

1. WP T1 – Identification of innovative solutions and Action plan definition
2. WP T2 – Testing phase
3. WP T3 – Networking and training on Green and intermodal solutions

WP T1 – identification of innovative solutions and Action plan definition

Within first technical work package (WP T1) several activities were performed:

A) Replicability research and analysis replicable operational and technological solutions
B) Environmental assessment
C) Joint Action plan definition

Activities have been started in June 2019 and finalised in September 2020.

A) Replicability research and analysis replicable operational and technological solutions

Partnership has made a general overview of existing solutions for lowering airports/ports environmental impact and for intermodal connection of ports/airports with other means of transportation. Within this activity SWOT analysis of each project partner was performed to assess current situation and fields for improvement. Also, international investigation research was conducted in order to identify and analyse the best solutions already implemented worldwide that can be easily implemented in Adriatic region.

One of the main focus areas of international investigation included on-going operational and technical initiatives for making ports/airports environmentally friendly with particular attention to maintenance activities.

Summary of practical sustainable applications to achieve carbon reductions at airport and port infrastructures are as follows:

Solution	**Brief description**	**Port reference case studies**	**Airport reference case studies**
Solar panels	Solar panels installed in different areas of the port/airport (e.g., rooftops of buildings and warehouses) for generating renewable energy.	Rotterdam, Amsterdam, and Gothenburg	Copenhagen, and Helsinki Airport
Geothermal heat pump/ Aquifer thermal energy storage[1]	Renewable thermal energy for large heating and cooling loads. Cooling/heating system employs a water-based thermal energy storage system that stores heat/cold in ground-water reservoirs.	Marseille	Paris-Orly, Nashville, Calgary, Stockholm-Arlanda, and Copenhagen Airport
Energy monitoring system	Monitoring system of the energy consumption of airport/port equipment, buildings and other facilities for supporting decision-making and implementation of measures for improving energy efficiency.	Valencia, Koper, and Jade Weser Port	Copenhagen Airport
Smart grid	Electricity network based on digital technology that can cost-efficiently integrate the behaviour and actions of all generators and consumers that are connected to the grid.	Antwerp	-

[1] Baxter et al. (2018). An assessment of airport sustainability, Part 2—Energy management at Copenhagen Airport. *Resources*, *7*(2), 32.

Daylighting strategy	A daylighting strategy can reduce electricity for lighting and peak electrical demand, cooling energy and peak cooling loads, maintenance costs associated with lamp replacement, and electrical service to the building. Maximize south glazing and minimize east- and west-facing glass[2].	Yokohama	Denver, and San Francisco Airport
Green roofs	Green roofs are covered with vegetation and a growing medium planted over a waterproofing membrane. When weight restrictions need to be considered, it is possible to utilize substrates that provide an adequate nutrient supply with relatively low specific weight. Main environmental goals: absorbing rainwater, providing insulation, and helping to mitigate the heat island effect in the built environment.	Värtahamnen, and Copenhagen	Frankfurt, Ibiza, Munich Airport, Paris Orly, and Bordeaux–Mérignac Airport
Concrete pavement instead of asphalt	Pavers are lower maintenance and generally have a longer lifespan compared to asphalt.	Värtahamnen	-
LED	Light emitting diode (LED) is a highly energy efficient lighting technology.	Venice, Hamburg, and Los Angeles	Stockholm Arlanda, Copenhagen, Schiphol, and Oslo Airport

Source: international investigation ADRIGREEN

For more details, please see related document International investigation ADRIGREEN.

B) Environmental assessment

Next step in project implementation comprised of producing Environmental Impact Assessment (EIA) for each project partner based on ad-hoc guidelines produced by technical expert in the project, Polytechnic University of Marche. In order to asses current situation in each partner, evaluation grid for EIA was produced to cover different environmental aspects; environmental impact of local air quality, waste and water management, energy consumption, carbon footprint and noise pollution.

C) Joint action plan definition

[2] https://www.lrc.rpi.edu/programs/daylighting/pdf/guidelines

Joint action plan definition has been produced by Polytechnic University of Marche with recommendations for improvement for each type of environmental activitiy (*please see: Adrigreen_WP3_D3_200218_Final*):

Within ADRIGREEN project Joint action plan definition, following measures were underlined regarding decreasing of electricity consumption and carbon footprint.:

General action	Specific action	Metrics	Port reference case studies
Decreasing electricity consumption	Light-emitting diodes (LED) lightning	Electricity consumption (kWh); GHG emissions (CO2eq)	P2 port (this study); Website port of Bilbao; Website port of Amsterdam; Website port of Tyne; Website port of Venice.
Decreasing electricity consumption	Energy monitoring system	Electricity consumption (kWh); GHG emissions (CO2eq)	Website port of Koper; Website JadeWeser Port; Website port of Valencia.
Decarbonizing electricity consumption	Photovoltaic or solar panel	Electricity consumption (kWh); GHG emissions (CO2eq)	Website port of Rotterdam; Website port of Antwerp; Website port of Gothenburg.
Decreasing electricity consumption	Passive house concept and eco-building standards	Electricity consumption (kWh); GHG emissions (CO2eq)	Website port of Amsterdam; Website port of Aalborg.
Decarbonizing electricity consumption	Geothermal energy plant for heating and cooling	Electricity consumption (kWh) from the commercial grid; GHG emissions (CO2eq)	Website port of Marseille.

Decarbonizing electricity consumption	Purchase of electricity generated from a mix of renewable energy sources	GHG emissions (CO_2eq); Amount of renewable energy purchased by the port, as a percentage of total energy consumed	Website port of Vancouver.
Decarbonizing electricity consumption	Wave energy converters	Electricity consumption (kWh) from the commercial grid; GHG emissions (CO_2eq)	Port of Ostend.
GHG = Greenhouse Gases			

Source: Adrigreen_WP3_D3_200218_Final

Since within ADRIGREEN project Dubrovnik Port pilot action comprises of purchasing of electric vehicles in order to replace existing diesel car park with electrical car park to achieve reduction of fossil fuel consumption, Dubrovnik Port pilot action is in line with recommendations specified in Joint Action plan definition.

WP T2 – Testing phase

Testing phase is the core phase of the project where identified solutions and best practices are to be put in place and tested within each partner pilot action. First deliverable of this work package related to Feasibility study for each pilot action where initial financial and environmental analysis have been performed.

Initial financial and environmental assessment of Dubrovnik Port pilot action demonstrated feasible and sustainable plan for reducing fuel consumption and CO2 emission by replacing old diesel car park with new electric car park.

This plan is to be carried on by Dubrovnik Port in the future until full replacement of old diesel vehicles with electric ones is achieved. In latter stages of this document Dubrovnik Port needs analysis as well as pilot action implemented and environmental analysis are explained.

III. DUBROVNIK PORT NEEDS ANALYSIS SUMMARY

Dubrovnik Port is located in the Dubrovnik-Neretva County. The Dubrovnik-Neretva County is the southernmost Croatian county. The main characteristic of this region is its transport isolation from the rest of Croatian territory and following that, from the rest of Europe, mostly as a result of physical separation from the rest of the state territory by the Bosnia and Herzegovina access corridor to the Adriatic. The region is also heavily lacking railway and highway infrastructures as the railway and highway links end at City of Ploce, a town located about 100 km North from the City of Dubrovnik.

The region's economy is mostly based on agriculture and tourism. Therefore, the traffic in Dubrovnik airport is mostly international traffic, including various destinations worldwide, especially during the summer season. This is why the area gravitating towards the Dubrovnik airport is much wider, including the Montenegrin territory and the territory of Bosnia and Herzegovina.

Dubrovnik is one of the most desirable tourist destinations in Europe and every year it records an increase in the number of tourists. According to the data of the Tourist Board of the City of Dubrovnik, in 2019 Dubrovnik was visited by 1,443,971 tourists, most of them during the summer months. In 2020 tourism has been affected by the COVID-19 pandemic crisis. From the very number of tourist arrivals, one can see the importance of tourism for Dubrovnik and its surroundings.

Thanks to its maritime position in the south of the Adriatic, Dubrovnik has a significant seaport whose primary function is receiving and supplying tourist boats. Over the centuries Dubrovnik, with its long seafaring and merchant history, has been a relation between the two parts of the Mediterranean. It had a very significant position at the eastern Adriatic seafaring route. With the development of commerce and the arrival of railways to Dubrovnik, a need for a new sea port appeared, because Old City Port could not fulfil the required standards of a cargo port neither by its position nor by its possibilities.

In the beginning the port was a cargo/passenger port and according to that there was one passenger quay, and the rest of the port was built as a sea port for cargo ships with lifts for loading and unloading of ship goods. Also, there was a terminal for the loading and unloading of rail wagons with which they transported different goods throughout the whole region. The port was specialized for the reception and transportation of wooden materials, but with further development of the port they built a cold storage for the reception and storage of easy damageable alimentary products. Also, there was built one terminal for the reception of passengers with restaurants and other facilities necessary for passenger transportation.

The Port of Dubrovnik is categorized as a passenger port open to public traffic, it is one of the six ports of international economic interest for the Republic of Croatia. The management of this port is directly the responsibility of the Ministry of the Sea, Transport and Infrastructure, the Maritime Transport Administration, the Maritime Property and the Port.

Due to the presence of certain types of traffic, the port of Dubrovnik stands out among the ports in the Croatian part of the Adriatic with its orientation to cruiser traffic.

In the last decade Dubrovnik has become a significant cruise ship destination in Adriatic Sea, namely the second one after Venice. The connectivity between Airport and Port is of major interest from environmental and industrial point of view. Also, it is important to highlight that there is only one route (a national road) between the Airport and the Port. This represents a significant infrastructural challenge to overcome, especially during tourist season. Dubrovnik Airport is in close relation with Dubrovnik Port, to monitor and organize transfers between the airport and port, and there are also collaborating on a number of projects. Such projects range from dedicated business projects such as Home Port for cruise ships, to more public ones such as projects supported by EU founding.

There are other emerging environmental challenges that were identified in recent years. Such new challenges are mostly due to the increase of traffic and the introduction of new port infrastructure. The additional maneuvering areas, buildings and facilities need to be integrated in existing systems and exploited in efficient way with lesser possible negative environmental effects.

In order to cope with new environmental challenges, Dubrovnik Port Authority has planned to increase the level of multimodality / intermodality and environmental performance at the airport through number of dedicated projects.

Dubrovnik Port Authority pilot action includes purchasing of electric car and electric moped, covering the following pilot action field:

- ➢ adoption of smart solutions to reduce energy consumption
- ➢ implementation of integrated timetabling and information for passengers that must continue their travel by other means of transport

Gained experience and benchmark information will provide inputs for future sustainable development of the whole region.

IV. DESCRIPTION OF PILOT ACTION IMPLEMENTED

Dubrovnik Port Authority pilot action implemented is in compliance to pilot action field identified within the project: *"adoption of smart solutions to reduce energy consumption"*; and is divided into two main areas / types of vehicles purchased:

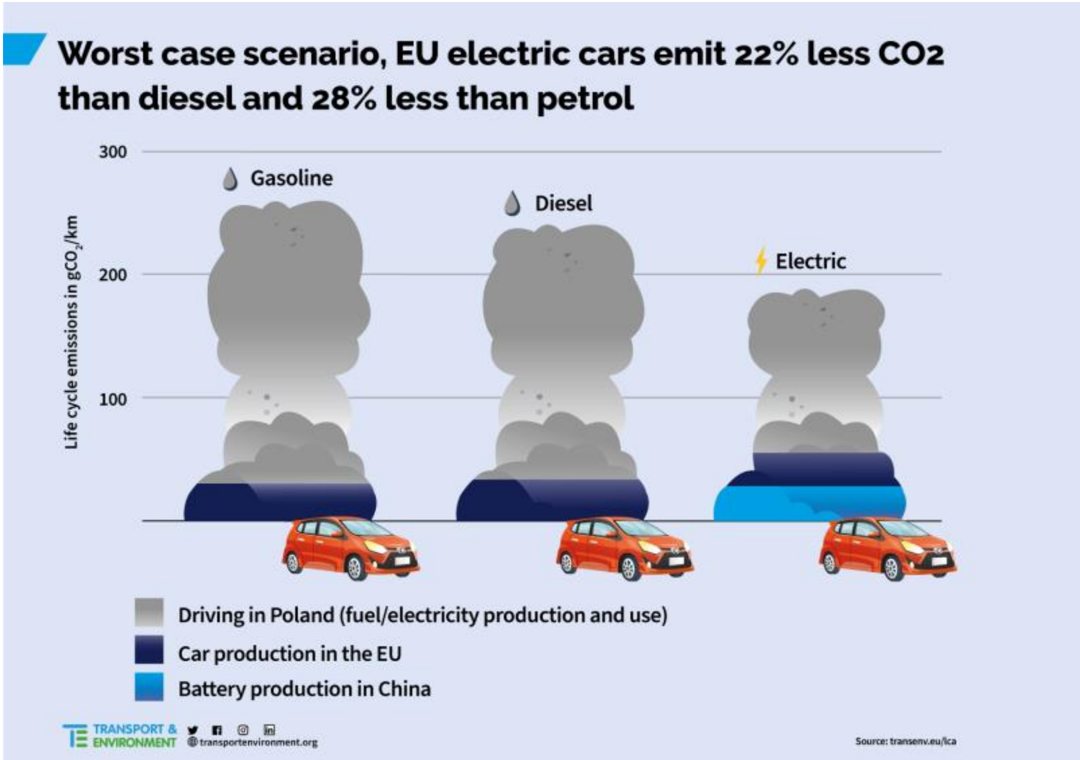
- ➢ electric car (smart EQ forfour)
- ➢ electric moped (SUNRA- Hawk)

According to the need's analysis performed, Dubrovnik Port Authority has identified following fields for improvement in landside and airside area:

- ➢ energy efficiency improvements within ports processes,
- ➢ cost effective optimisation of business processes.

Purchase and implementation of the electric vehicle will significantly lower CO2 emission and it will reduce energy consumption in performing daily processes within Dubrovnik Port Authority. Also, since these vehicles is used on the landside area, it will be visible to the stakeholders and general public contributing to the ports green field policy and zero emission strategy.

Electric cars in Europe emit, on average, almost three times less CO2 than equivalent petrol or diesel cars. That's according to a new online tool that allows the public to compare the lifecycle emissions of an EV to fossil-fuel vehicles. The tool draws on the most up-to-date data to allow users to compare the vehicles in several different scenarios based on vehicle segment, where the battery was produced, and in what country the car was driven. Even in the worst case scenario, an electric car with a battery produced in China and driven in Poland still emits 22% less CO2 than diesel and 28% less than petrol, the tool shows. In the best case scenario, an electric car with a battery produced in Sweden and driven in Sweden can emit 80% less CO2 than diesel and 81% less than petrol.



Additionally, daily operative activities performed by Dubrovnik Port Authority staff were supported mainly by several petrol vehicles.

Prior to ADRIGREEN project daily operative activities were performed by several vehicles on petrol fuel. Within ADRIGREEN project Dubrovnik Port Authority has purchased electric car and electric moped for day to day port staff activities, and with usage of these electric car and moped energy consumption and airborne pollutant emissions will be reduced.

One of the Adrigreen project priority is implementation of integrated timetabling and information for passengers that must continue their travel by other means of transportation.

Each passenger should be able to:

- plan her/his trips by choosing the best travel option with regards to her/his needs;
- get real-time information about waiting times when accessing the service;
- get information about the trip and possible emergency events (delays, incidents, etc.) - including available transfer options - while travelling.

The Dubrovnik Port Authority intends to install variable message panels to give updated on-time information. The panel will be equipped with software able to guarantee an efficient and on-time information flow between different sources of information (ferry related information as well as local public transport).

V. FINANCIAL AND ENVIROMENTAL ANALYSIS

<u>Financial analysis</u>

Dubrovnik Port Authority has performed financial analysis of equipment purchased and used. In conducting financial analysis following assumptions were taken into the consideration:

- purchase price of new vehicle and old (replaced vehicle),
- additional yearly maintenance expenses,
- electric battery change each five years,
- discount interest rate of 3% (source: Croatia National Bank decision from September, 2017),
- economic life usage period of vehicles (8 years).

Other information:

- electric vehicle was purchased and put in use in August 2019.
- electric moped was purchased and put in use in June 2019.
- three electric bicycles were purchased and put in use in May 2021.

According to financial analysis, purchase of electric vehicle and moped is more feasible on respected period. Financial analysis is presented in Feasibility Study for Dubrovnik Port pilot action, for more details please see related document.

1. WASTE MANAGEMENT VEHICLE ANALYSIS

FINANCIAL ANALYSIS OF EL.VEHICLE

VALUE IN CONSTANT PRICES					
	Year	Purchased price	Operating expenditures (service, fuel....)	Residual value	Net cash flow
0	2019	181,625			181,625
1	2020		3,800		185,425
2	2021		5,800		191,225
3	2022		3,800		195,025
4	2023		5,800		200,825
5	2024		32,300		233,125
6	2025		5,800		238,925
7	2026		3,800		242,725
8	2027		5,800	0	**248,525**
	SUM	**181,625**	**66,900**		

DISCOUNT VALUES (3%)					
Year	Purchased price	Discount values 3%	Operating expenditures (service, fuel....)	Residual value	Net cash flow
2019	181,625				181,625
2020		0.9709	3,689.42	0	185,314
2021		0.9426	5,467.08	0	190,782
2022		0.9151	3,477.38	0	194,259
2023		0.8885	5,153.30	0	199,412
2024		0.8375	27,051.25	0	226,463
2025		0.8375	4,857.50	0	231,321
2026		0.8131	3,089.78	0	234,411
2027		0.7894	4,578.52	0	**238,989**
SUM	**181,625**		**57,364.23**		

batery change	31,000
energy consumption	1,300
services	2,500
tyres	2,000

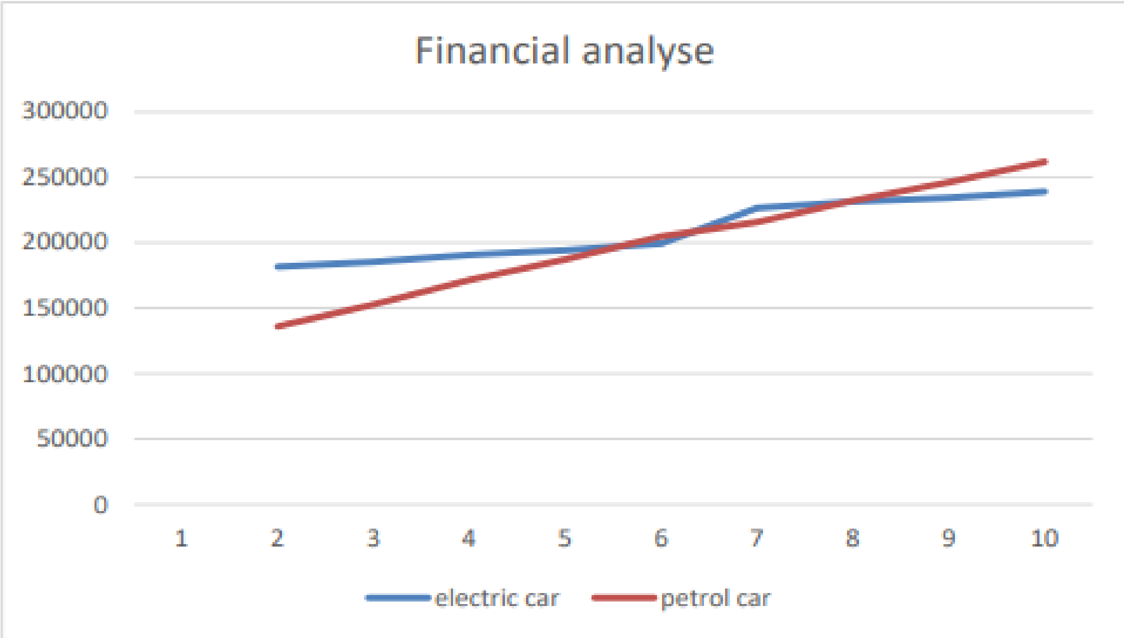
FINANCIAL ANALYSIS OF PETROL VEHICLE

VALUE IN CONSTANT PRICES					
	Year	Purchased price	Operating expenditures (service, fuel....)	Residual value	Net cash flow
0	2019	136,000			136,000
1	2020		17,300		153,300
2	2021		19,800		173,100
3	2022		17,300		190,400
4	2023		19,800		210,200
5	2024		12,800		223,000
6	2025		19,800		242,800
7	2026		17,300		260,100
8	2027		19,800	0	**279,900**
	SUM	**136,000**	**143,900**		

DISCOUNT VALUES (3%)					
Year	Purchased price	Discount values 3%	Operating expenditures (service, fuel....)	Residual value	Net cash flow
2019	136,000				136,000
2020		0.9709	16,796.57	0	152,797
2021		0.9426	18,663.48	0	171,460
2022		0.9151	15,831.23	0	187,291
2023		0.8885	17,592.30	0	204,884
2024		0.8375	10,720.00	0	215,604
2025		0.8375	16,582.50	0	232,186
2026		0.8131	14,066.63	0	246,253
2027		0.7894	15,630.12	0	**261,883**
SUM	**136,000**		**125,882.83**		

energy consumption	12,800
services	4,500
tyres	2,500

According to financial analysis performed, electric vehicle costs for period of 8 years are 238.989 thousand HR compared to 261.883 thousand HRK for petrol vehicle, which makes it more feasible and cost effective for the company.



2. ELECTRIC MOPED

VALUE IN CONSTANT PRICES- electric moped					
	Year	Purchased price	Operating expenditures (service, fuel....)	Residual value	Net cash flow
0	2019	22,488			22,488
1	2020		500		22,988
2	2021		1,000		23,988
3	2022		500		24,488
4	2023		1,000		25,488
5	2024		4,000		29,488
6	2025		1,000		30,488
7	2026		500		30,988
8	2027		1,000	0	**31,988**
	SUM	**22,488**	**9,500**		

DISCOUNT VALUES (3%)					
Year	Purchased price	Discount values 3%	Operating expenditures (service, fuel....)	Residual value	Net cash flow
2019	22,488				22,488
2020		0.9709	485.45	0	22,973
2021		0.9426	942.60	0	23,916
2022		0.9151	457.55	0	24,374
2023		0.8885	888.50	0	25,262
2024		0.8375	3,350.00	0	28,612
2025		0.8375	837.50	0	29,450
2026		0.8131	406.55	0	29,856
2027		0.7894	789.40	0	**30,646**
SUM	**22,488**		**8,157.55**		

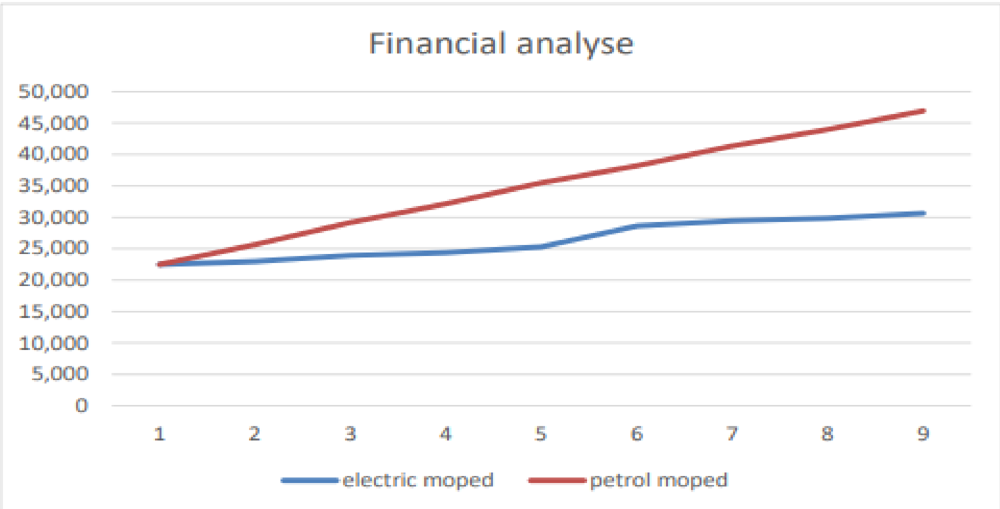
batery change	3,000
Energy consumption	250
services	250
tyres	500

	VALUE IN CONSTANT PRICES – petrol moped				
	Year	Purchased price	Operating expenditures (service, fuel….)	Residual value	Net cash flow
0	2019	19,000			22,488
1	2020		3,250		25,738
2	2021		3,750		29,488
3	2022		3,250		32,738
4	2023		3,750		36,488
5	2024		3,250		39,738
6	2025		3,750		43,488
7	2026		3,250		46,738
8	2027		3,750	0	**50,488**
	SUM	**22,488**	**28,000**		

DISCOUNT VALUES (3%)					
Year	Purchased price	Discount values 3%	Operating expenditures (service, fuel….)	Residual value	Net cash flow
2019	19,000				22,488
2020		0.9709	3,155.43	0	25,643
2021		0.9426	3,534.75	0	29,178
2022		0.9151	2,974.08	0	32,152
2023		0.8885	3,331.88	0	35,484
2024		0.8375	2,721.88	0	38,206
2025		0.8375	3,140.63	0	41,347
2026		0.8131	2,642.58	0	43,989
2027		0.7894	2,960.25	0	**46,949**
SUM	**22,488**		**24,461.45**		

energyconsumption	3,000
services	250
tyres	500

According to financial analysis performed, electric moped costs for period of 8 years are 30.646 thousand HR compared to 46.949 thousand HRK for petrol moped, which makes it more feasible and cost effective for the company.



Environmental analysis

Emissions of airborne pollutants (NOx and PM) and CO2 deriving from fossil fuel vehicles

For fossil fuel vehicles, the emissions of NOx, PM, and CO2 were evaluated following Tier 1 according to Ntziachristos et al. (2019), as follows:

$$\mathrm{E_i} = \sum\nolimits_{\mathrm{j}} \mathrm{EF_j} \times \mathrm{FC_j} \times \mathrm{U_l}$$

where $\mathrm{E_i}$ is the emission value of NOx [g], PM [g], and CO2 [kg]; $\mathrm{EF_j}$ is the emission factor specific for the type of fuel and the vehicle category (Table 1), [g/kg fuel] for PM and NOx; [kg CO2/kg fuel] for CO2; $\mathrm{FC_j}$ is the fuel consumption related to the j-category of vehicle (Table 2)[g/km]; $\mathrm{U_l}$ is the usage per year for the l-vehicle (Table 3), [km/year].

Table 1. Tier 1 emission factors for diesel and petrol passenger cars adapted from Ntziachristos et al. (2019).

Category	Fuel	Airborne pollutants and CO2	Unit of emisison factor	Emission factors
Passenger car	Diesel	NOx	[g/kg fuel]	12.96
Passenger car	Diesel	PM	[g/kg fuel]	1.10
Passenger car	Diesel	CO2	kg CO2/kg fuel	3.169
Passenger car	Petrol	NOx	[g/kg fuel]	8.73
Passenger car	Petrol	PM	[g/kg fuel]	0.03
Passenger car	Petrol	CO2	kg CO2/kg fuel	3.169

Table 2. Typical fuel consumption per km, by category of vehicle and type of fuel (Tier 1) adapted from Ntziachristos et al. (2019).

Vehicle category	Fuel	Typical fuel consumption [g/km]
Passenger car	Diesel	60
Passenger car	Petrol	70

Table 3. Usage per year of the fossil fuel vehicles that are going to be replaced at Dubrovnik Port.

	Fuel	Vehicle category	Usage* [km/year]
Vehicle	Diesel	Passenger car	13,200
Vehicle	Petrol	Passenger car	13,200

*Values were estimated based on the utilization of the electric vehicles reorted by Dubrovnik Port.

Emissions of greeenhouse gases deriving from electric vehicles

For each electric vehicle, the CO2 equivalent emission (E_i) was evaluated as follows:

$$E_i = \sum_j FC_j \times EF_j \times T_i$$

where FC_j is electricity consumption related to the battery capacity of electric vehicles [kWh]; EF_j is the emission factor of 205 g CO2 eq/kWh that was determined for Croatia (Koffi et al. 2017); T_i is the number of recharge per year for the i-vehicle, [-].

For the i-vehicle, the number of recharge per year (T_i) was obtained as follows:

$$T_i = \frac{U_i}{R_i}$$

whereU_i is the usage per year for the i-vehicle (Table 4), [km/year]; $R_i$is the range of the i-type of battery reported by the manufacturer, [km].

Table 4 Usage per year and technical specifications of the electric vehicles purchased to replace fossil fuel vehicles at Dubrovnik Port.

	Type of vehicle	**Manufacturer**	**Number of units**	**Utilization each unit [km/year]**	**Engine power [kW]**	**Range [km]**	**Battery capacity [Wh]**
[a,]Electric car	Smart EQ forfour	Mercedes - Benz	1	14400	60	105	16700

[b]Electric scooter	HAWK	SUNRA	1	12000	3	60	1440

[a] https://ev-database.uk/car/1232/Smart-EQ-forfour

[b] http://allbikeprice.com/sunra-hawk-electric-scooter-price-specifications/

Results

Each year, the fossil fuel vehicles emits about 10.3 times the greenhouse gases deriving from the electricity utilised by the electric vehicles (Figure 1). End of waste and the life cycle assement of diesel and electric vehicles were not assessed.

Local emissions of airborne pollutants such as NOx and particulate matter (PM) is assumed to be null for the electic vehicles. However, the emission of airborne pollutants should be considered depending on the location of production and the technology utlised for producing electicity.

On the contrary, utilising the fossil fuel vehicles would result in local emissions of NOx and PM (Figure 2).

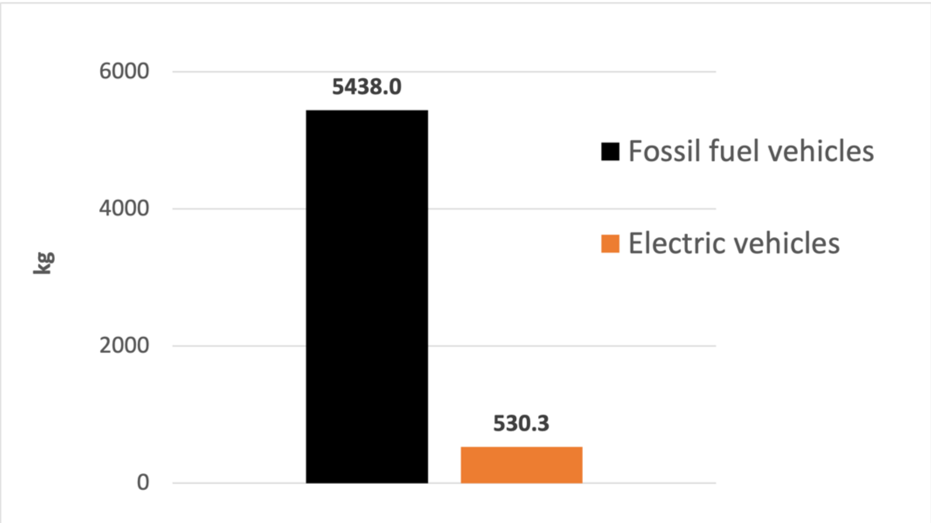


Figure 1. Comparison between greenhouse gases emissions deriving from diesel vehicles (CO_2) and electric vehicles (CO_2 eq) per year.

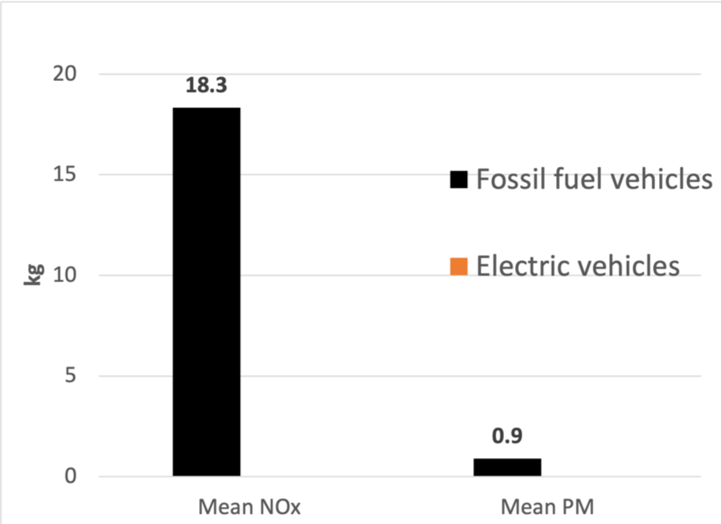


Figure 2. Comparison between local emissions of airborne pollutants (i.e., NOx and PM) deriving from diesel vehicles and electric vehicles per year.

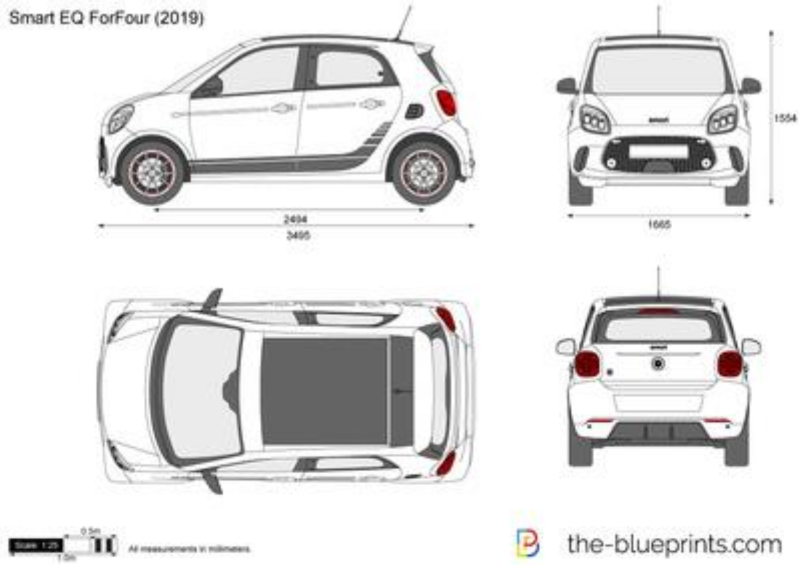
References

Ntziachristos, L.; Samaras, Z., et al. 2019. EMEP/EEA air pollutant emission inventory guidebook 2019. Available at https://www.eea.europa.eu/publications/emep-eea-guidebook-2019/part-b-sectoral-guidance-chapters/1-energy/1-a-combustion/1-a-3-b-i/view

Koffi, B.; Cerutti, A.; Duerr, M.; Iancu, A.; Kona, A.; Janssens-Maenhout, G. 2017. CoM Default Emission Factors for the Member States of the European Union - Version 2017, European Commission, Joint Research Centre (JRC) [Dataset]. Available at http://data.europa.eu/89h/jrc-com-ef-comw-ef-2017

VI. ANNEX I – TECHNICAL SPECIFICATIONS

Figure 1. - <u>Electric vehicle Smart EQ forfour</u>



Performance

Acceleration 0 - 100 km/h	12.7 sec	Total Power	60 kW (82 PS)
Top Speed	130 km/h	Total Torque	160 Nm
Electric Range	90 km	Drive	Rear

Battery and Charging

Battery Capacity	17.6 kWh	Battery Useable*	16.7 kWh

Europe

Charge Port	Type 2	Fastcharge Port	-
Port Location	Right Side - Rear	FC Port Location	-
Charge Power	4.6 kW AC	Fastcharge Power (max)	-
Charge Time (0->90 km)	4h30m	Fastcharge Time	-
Charge Speed	21 km/h	Fastcharge Speed	-

Click here for all charging information

Energy Consumption

EVDB Real Range

Range	90 km	CO2 Emissions	0 g/km
Vehicle Consumption	186 Wh/km	Vehicle Fuel Equivalent	2.1 l/100km

NEDC Ratings

Range	160 km	CO2 Emissions	0 g/km
Rated Consumption	131 Wh/km	Rated Fuel Equivalent	1.5 l/100km
Vehicle Consumption	104 Wh/km	Vehicle Fuel Equivalent	1.2 l/100km

Real Energy Consumption

between 119 - 278 Wh/km

City - Cold Weather	176 Wh/km	City - Mild Weather	119 Wh/km
Highway - Cold Weather	278 Wh/km	Highway - Mild Weather	209 Wh/km
Combined - Cold Weather	223 Wh/km	Combined - Mild Weather	159 Wh/km

Indication of real-world energy use in several situations. Cold weather: 'worst-case' based on -10°C and use of heating. Mild weather: 'best-case' based on 23°C and no use of A/C. The energy use will depend on speed, style of driving, climate and route conditions.

Dimensions and Weight

Length	3495 mm	Cargo Volume	185 L
Width	1665 mm	Cargo Volume Max	975 L
Width with mirrors	No Data	Cargo Volume Frunk	No Data
Height	1554 mm	Roof Load	0 kg
Wheelbase	2494 mm	Tow Hitch Possible	No Data
Weight Unladen (EU)	1200 kg	Towing Weight Unbraked	0 kg
Gross Vehicle Weight (GVWR)	1560 kg	Towing Weight Braked	0 kg
Max. Payload	435 kg	Vertical Load Max	No Data

Miscellaneous

Seats	4 people	Car Body	Hatchback
Isofix	Yes, 2 seats	Segment	A - Mini
Turning Circle	9.1 m	Roof Rails	No
Platform	No Data	EV Dedicated Platform	No Data

Home and Destination Charging (0 -> 100%)

Charging is possible by using a regular wall plug or a charging station. Public charging is always done through a charging station. How fast the EV can charge depends on the charging station (EVSE) used and the maximum charging capacity of the EV. The table below shows all possible options for charging the Smart EQ forfour. Each option shows how fast the battery can be charged from empty to full.

Europe

Charging an EV in Europe differs by country. Some European countries primarily use 1-phase connections to the grid, while other countries are almost exclusively using a 3-phase connection. The table below shows all possible ways the Smart EQ forfour can be charged, but some modes of charging might not be widely available in certain countries.

Type 2 (Mennekes - IEC 62196)

Charging Point	Max. Power	Power	Time	Rate
Standard 4.6 kW On-Board Charger				
Wall Plug (2.3 kW)	230V / 1x10A	2.3 kW	8h45m	10 km/h
1-phase 16A (3.7 kW)	230V / 1x16A	3.7 kW	5h30m	16 km/h
1-phase 32A (7.4 kW)	230V / 1x20A	4.6 kW †	4h30m	20 km/h
3-phase 16A (11 kW)	230V / 1x16A	3.7 kW †	5h30m	16 km/h
3-phase 32A (22 kW)	230V / 1x20A	4.6 kW †	4h30m	20 km/h
Optional 22.0kW On-Board Charger *				
Wall Plug (2.3 kW)	230V / 1x10A	2.3 kW	8h45m	10 km/h
1-phase 16A (3.7 kW)	230V / 1x16A	3.7 kW	5h30m	16 km/h
1-phase 32A (7.4 kW)	230V / 1x32A	7.4 kW	2h45m	33 km/h
3-phase 16A (11 kW)	400V / 3x16A	11 kW	2 hours	45 km/h
3-phase 32A (22 kW)	400V / 3x32A	22 kW †	55 min	98 km/h

Figure 2. – Electric moped Sunra Hawk

Power 1.8 kW (2.4 hp)

- Weight 83 kg
- LiFePo4 (LFP) battery
- Battery life 800 cycles
- Range 130 km
- Charging time 4 hours