JOINT ACTIONS PLANS FOR PORTS AND AIRPORTS

Final Version of 31/12/2020

Deliverable Number D.3.3.1/2

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Project Acronym	ADRIGREEN
Project ID Number	10044741
Project Title	Green and Intermodal solutions for Adriatic airports and ports
Specific objective	4.1
Work Package Number	3
Work Package Title	Identification of innovative solutions and Action Plan Definitions
Activity Number	3
Activity Title	Joint Action Plan Definitions
Partner in Charge	Marche Polytechnic University
Status	Final
Distribution	Public

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Introduction

The present report is the third deliverable of WP3 of the Green and Intermodal Solutions for Adriatic Ports and Airports "ADRIGREEN" project. ADRIGREEN is a project under the INTERREG V-A Italy Croatia CBC Programme 2014-2020.

With the first deliverable under WP3, the Adrigreen team of Marche Polytechnic University collected and analyzed replicable operational and technological solutions aimed at improving intermodal connections and reducing the environmental impact of airports and ports.

A literature review was performed about existing solutions and case studies implemented at airports and ports. A Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis was performed for the existing solutions.

Whenever relevant to the present report, the information related to the SWOT-strategies section of the first deliverable of WP3 were considered for the evaluation of Strengths/Weaknesses, and Opportunities/Threats of the action. The general/literature SWOT approach applies to the structure of the SWOT-strategies section of the present report, the main general rules being the ones that follow.

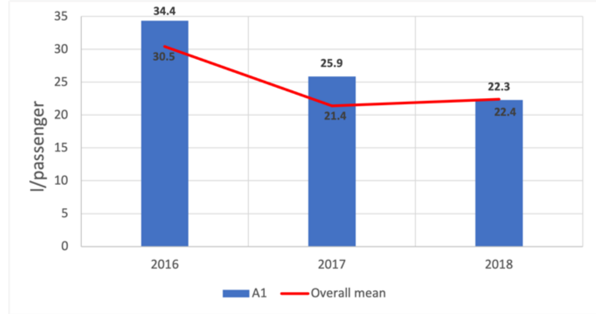
- "MATCH Strengths and Opportunities". Use internal Strengths to take advantage of external Opportunities.
- "OPPOSE Strengths to Threats". Use internal Strengths to minimize external Threats.
- "OPPOSE Opportunities to Weaknesses". Improve internal Weaknesses by taking advantage of external Opportunities.
- "DISRUPT Weaknesses and Threats". Work to eliminate internal Weaknesses especially to avoid external Threats.
- "CONVERT Weaknesses into Strengths" Apply best practices aiming at turning Weaknesses into Strengths.
- "AVOID converting Strengths into Weaknesses". Prevent wrong approaches that may convert Strengths into Weaknesses.
- "CONVERT Threats into Opportunities". Move towards strategic directions that may convert Threats into Opportunities (scenarios turning Threats into Opportunities)
- "AVOID converting Opportunities into Threats". Prevent inadequate planning that may convert Opportunities into Threats (scenarios turning Opportunities into Threats).

Within the second deliverable under WP3, partners have found the results of an environmental assessment based on the data collected by the Adrigreen airports and ports according to our guidance.

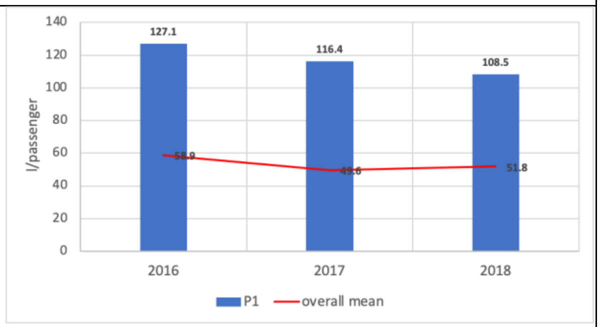
Data analysis involved the time period 2016–2018 and it was possible to perform both an internal and an external benchmarking for the Adrigreen partners that provided all the data encompassing the entire time period.

Through our internal benchmarking, an airport/port can now analyze its own performance over time. For example, the second deliverable reported time series of several performance indicators for each Adrigreen partner (Figs. i – ii). We wish to stress that only few partners were apparently aware of their performances. In some cases they experienced severe difficulties even to find the relevant information such as bills, counts etc.

i) A1 Airport's water consumption per passenger in the time period 2016–2018.

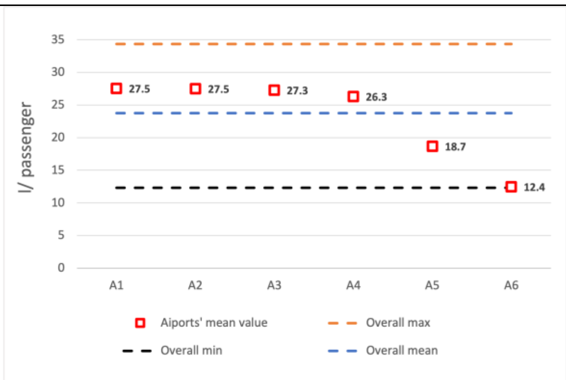


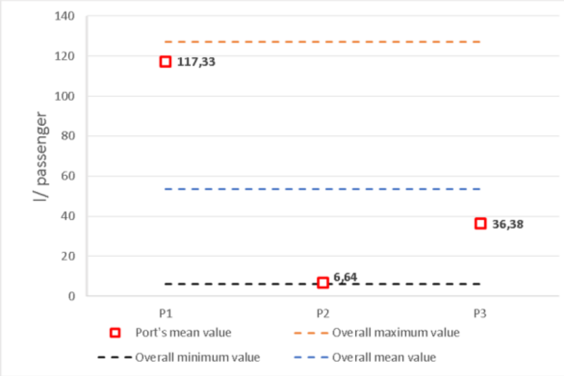
ii) P1 Port's water consumption per passenger in the time period 2016–2018.



Through our external benchmarking, an airport/port can now compare its own performance against other partners. For example, the second deliverable reported comparisons between the performance indicators for each Adrigreen partner and the overall minimum, maximum and mean values (Figs. iii – iv).

iii) Airports' mean water consumption and overall maximum, minimum and mean water consumption per passenger in the time period 2016–2018.



iv) Ports' mean water consumption and overall maximum, minimum and mean water consumption values per passenger in the time period 2016–2018.


Adrigreen partners provided basic information in order to perform a SWOT analysis dedicated to the possible actions to be implemented. We would like to stress the fact that A4 airport was not supposed to carry out data collection for environmental analysis and they did not receive any funding for this task. However, they voluntarily performed environmental data collection to help the Adrigreen team of Marche Polytechnic University. We really appreciated it and we would like to thank the Adrigreen team of A4 Airport once more for their support.

For the environmental assessment of the Adrigreen airports and ports reported in the second deliverable, the investigated topics were:

- water consumption,
- waste management,
- energy consumption,
- greenhouse gases emissions deriving from the above activities,
- multimodality,
- noise pollution.

Within this document, a series of pilot actions is presented based on the information collected in the first deliverable and on the environmental benchmarking reported within the second deliverable. As a general rule, we scrutinized relevant pilot actions belonging to two groups.

The first group is made of all the proposals presented within the first deliverable i.e. the possible applicable pilot actions collected within the relevant literature and/or case studies. The pilot actions were chosen according to their applicability within the scope of the project following the SWOT analysis and the results of environmental assessment/benchmarking. Due to such benchmarking and SWOT analysis, a single pilot action may be suitable either to all the ports and/or the airports or to some of them only.

The second group is made of pilot actions deriving directly from the scrutiny of environmental assessment performed over Adrigreen port/airports as reported in deliverable two, including the related SWOT analysis. In this case, indicators showed how one or more partners "behave" better in a specific environmental field. A subsequent analysis let us understanding the local actions implemented so to reach such results and to identify the proper pilot actions to be realized within Adrigreen project. Quite obviously such actions are applicable to some of the partners only.

The environmental analysis performed outlined that the environmental footprint of the Adrigreen airports and ports could be reduced (thus improved) by applying actions regarding:

- water consumption,
- waste management,
- energy consumption,
- greenhouse gases emissions deriving from the activities listed above,
- sustainable transportation of passengers from/to the airport/port infrastructures.

For water and energy consumption, the performances of Adrigreen ports and airports are compared with the data calculated for the other Adrigreen partners and presented in terms of CO2 emissions and budget. In fact, we considered useful to highlight both the possible greenhouse gases abatements and the possible economic benefits in terms of budget reduction.

Greenhouse gases emissions deriving from airport and port infrastructures can also be considered as a general proxy variable for airborne pollutants emissions. As a very general rule, lower greenhouse gases emissions will also mean lower airborne pollutant emissions. Therefore, actions that result in reducing the carbon footprint of a given activity should also reduce the global and/or local emissions of air pollutants. For example, an action that cuts local fuel consumption (e.g. replacing fuel-driven vehicles with electric ones) has a positive impact on both greenhouse gas emissions (globally reducing them) and air pollutant emissions (virtually zeroing them locally and reducing them globally). However, care must be taken when analyzing the global and local impacts of an action since this rule is not always so straightforward.

The proposed actions are summarized in tables, each row outlining the following information:

- general action,
- specific short-term/long term action,
- metrics,
- applicability/status at each Adrigreen airport/port
- relationship with Strengths/Weaknesses at each Adrigreen airport/port
- relationship with Opportunities/Threats at each Adrigreen airport/port.

Most short-term initiatives require short/medium start-up times, minimal implementation and design complexity, and relatively low costs. All permission procedures can be usually managed directly by the airport/port authority or by the stakeholders involved. Long-term initiatives are characterized by prolonged start-up times and high complexity of design and implementation. Authorization procedures will mainly depend on local, regional, or national authorities/agencies.

For the applicability/status of each specific action, a range of values from 0 to 3 was considered as depicted in Table 1.

APPLICABILITY/STATUS	DESCRIPTION
0	NOT APPLICABLE OR NOT SUGGESTED
1	APPLICABLE AND SUGGESTED
2	PARTIALLY IMPLEMENTED
3	IMPLEMENTED

Table 1 Numerical indexes recapping the status of implementation of a specific activity at specific port/airport.

For the columns of the tables associated to the SWOT analysis, the potential interactions of each specific action with the Strengths/Weaknesses and Opportunities/Threats, highlighted by the Adrigreen partners, are summarised through numerical indexes. A4 Airport voluntarily took part to WP3 but did not provide SWOT analysis. Therefore, the Strengths/Weaknesses, and Opportunities/Threats columns were not filled for A4 Airport. For the Strengths/Weaknesses and for Opportunities/Threats, a range of values from -2 to 2 was considered as depicted in Table 2 and Table 3.

STRENGTHS/WEAKNESSES INDEX	DESCRIPTION
-2	The implementation of the specific action is expected to have minor or negative influence on the Strengths whilst boosting several Weaknesses of the airport/port.
-1	The implementation of the specific action is expected to have minor or none influence on the Strengths whilst boosting one or more Weaknesses of the airport/port.
0	The implementation of the specific action is expected either not to interact with Strengths and Weaknesses of the airport/port or to balance the related effects.
1	The implementation of the specific action is expected to boost one or more Strengths whilst having minor/no influence on the Weaknesses of the airport/port.
2	The implementation of the specific action is expected to boost several Strengths whilst having minor or positive influence on the Weaknesses of the airport/port.

Table 2 Numerical indexes recapping potential positive/negative synergies with Strengths/Weaknesses of a specific action at specific port/airport.

OPPORTUNITIES/THREATS INDEX	DESCRIPTION
-2	The implementation of the specific action is expected to have minor or negative influence on the Opportunities whilst boosting several Threats of the airport/port.
-1	The implementation of the specific action is expected to have minor or none influence on the Opportunities whilst boosting one or more Threats of the airport/port.
0	The implementation of the specific action is expected either not to interact with Opportunities and Threats of the airport/port or to balance the related effects.
1	The implementation of the specific action is expected to boost one or more Opportunities whilst having minor/no influence on the Threats of the airport/port.
2	The implementation of the specific action is expected to boost several Opportunities whilst having minor or positive influence on the Threats of the airport/port.

Table 3 Numerical indexes recapping potential positive/negative synergies with Opportunities/Threats of a specific activity at specific port/airport.

Steps for the pilot actions

1. Driving factors evaluated through a qualitative analysis such as a SWOT analysis and/or data collection for the assessment of the consumption trend and the environmental performance preceding the pilot action. Definition of key performance indicators.

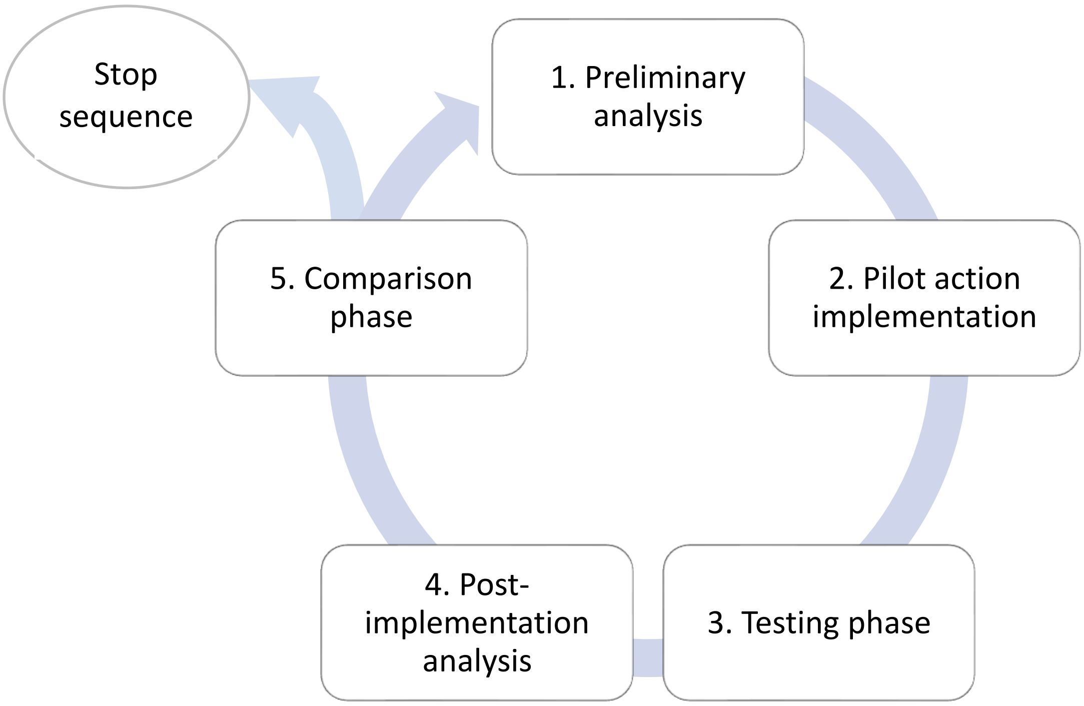
2. Identification of the pilot action to implement based either on the results of Benchmarking within Adrigreen partners or upon case studies reported by literature upon similar airport/port infrastructures.

3. Testing phase and collection of qualitative and/or quantitative data.

4. A qualitative analysis such as SWOT analysis and/or collection of data for the assessment of the consumption trend and the environmental performance resulting from the implementation of the pilot action. Evaluation of key performance indicators. Evaluation of the performance of the airport/ port infrastructure over time for internal benchmarking.

5. Comparison between step 1 and step 4 qualitative and/or quantitative data. If the desired performance levels have been reached, the sequence ends otherwise to reach the objectives it restarts from step 1.

Figure 1 Sequence to define and evaluate pilot action initiatives.



The main sections of this report cover the following issues:

1. Pilot actions for Adrigreen airports
2. Pilot actions for Adrigreen ports
3. Sustainable solutions for the transport of passengers from/to airport/port infrastructures
4. Annex: an example of the environmental analysis related to greenhouse gases and airborne pollutants emissions of a specific action.

Pilot actions for Adrigreen airports

Strengths, Weakness, Opportunities, and Threats analysis of Adrigreen airports

All the airports consider the location as Strength. Namely, A2, A3, A5, and A6 highlighted the proximity of the airports to the respective main urban centres while A1 highlighted its position within the region.

A common Strength of A1, A5, and A6 is their minor environmental disturbance, A5 and A6 also reporting good communication and coordination with the public administrations and other stakeholders involved in the management of environmental issues.

Another Strength of A5 and A6 is public transport, with frequent train calls for A5 and frequent bus calls for A6.

A1, A3, and A6 have tourist attractions nearby and serve a significant number of tourists.

Both A1 and A2 report likelihood of infrastructure enlargement. The current infrastructure of A2 was designed to serve about 3 to 5 times the present passenger traffic.

Traffic congestion of the access roads is a common Weakness of A5 and A6 and a potential Weakness of A2. Seasonality of passenger traffic is a Weakness both for A1 and A6 airports, whereas incoming touristic activities are not well developed at A3 Airport.

A2 Airport reported limited public-transport connections. Similarly, A5 Airport reported insufficient rail connections to some destinations of the area and no direct connection with the nearby port.

Investments for enhancing public transportation may represent a Threat for A3 and A6 airports. Urban planning and ownership of surrounding properties may pose a Threat to the potential expansion of A1 and A2. Coordination with involved stakeholder may pose a Threat to development of integrated tariff system and information at A5 Airport.

‘A1’ Airport – SWOT analysis

Strengths	**Weaknesses**
- Fully operational airport; - Minor environmental disturbances; - Land available for expansion; - Geographical location in the region; - Regional state support; - A small number of competitive airports for the region; - Large volume of receptive tourism; - Dependence on "external" gross domestic product (GDP) growth.	- Absence of domicile carrier; - Seasonal international traffic; - A small amount of cargo; - Limited population that would increase the output potential; - Marketing activities (tour operators) generally reach the norm in the "main" season; - Dependence on "external" GDP growth.
Opportunities	**Threats**
- Potential for GDP growth dependent on GDP; - Attracting new airlines (airline marketing); - Introduction of cruise and summer systems; - Potential receptive tourism (cooperation with tour operators) outside the "main" season; - Development of non-aviation activities (hotel, offices, advertising, car parking, etc.)	- Poor development in the tourism sector will reduce the window of Opportunity for airport development; - Danger of continued instability of the main target markets (northern European and ex EU countries); - Ownership of surrounding land.

'A2' Airport– SWOT analysis

Strengths	**Weaknesses**
- The airport is designed to serve up to 1 million passengers in its current configuration; - A quite large airport area with possibilities of expansion both in terms of passenger traffic, but especially cargo traffic; - Proximity to the main urban centres of two different provinces.	- Road connections are barely sufficient to manage current airport traffic, an increase in both passenger and cargo traffic must necessarily re-evaluate the access points to the infrastructure; - Collective public transport to connect the airport to nearby cities is still limited; - Incoming traffic is much higher than outcoming.
Opportunities	**Threats**
- The nearby area attract several forms of tourism (sports, congress, seaside, archaeological, food and wine and shopping); - The development of regional tourism projects of all kinds, especially with the countries of Eastern and Northern Europe, would increase airport traffic; - Possible enhancement of cargo, with the arrival of a multinational company centre less than 15 km away and the presence of a strong industrial presence in the nearby hinterland.	- Very populated area towards the sea makes expansion in that direction almost impossible; - Two large or medium/large airports within 150 km and one small airport within 50 km offer similar services with good connections which reduce the potential catchment area of the airport; - Long dialogues with the Province and the Region to have support for the development (including eco-sustainable) of the airport; - With the recent modernization of the highway and the high-speed rail network, the domestic traffic comes mainly by wheel or rail.

'A3' Airport – SWOT analysis

Strengths	Weaknesses
- Strong financial backing from Regional Government; - Non saturated capacity available for growth; - Small flexible organization; - Sound financials; - Closeness to city centres and easy access from highways; - Good touristic attractiveness (sea, mountains).	- Low awareness on the international markets; - Size still insufficient for full financial independency; - Low level of non-aviation revenues, especially from parking; - Incoming tourism activities not well developed; - Nearness of Rome airports served through highway.
Opportunities	**Threats**
- Attractiveness for airside business (hangars, new airline base); - Good relationship with largest low-cost carriers for promoting strong growth; - New real estate contracts from Regional entities.	- Further growth of Rome; - Investment on rail service to Rome; - Region gross domestic product growth.

'A5' Airport – SWOT analysis

Strengths	Weaknesses
- Proximity to the city; - Rail connection with the provincial capital; - There are no criticalities with the public administration and/or the local population of the nearby municipalities for noise, etc.	- Traffic congestion on the road to access to the airport; - Inefficient railway connection with different main towns of the nearby area; - No direct connection with the port.
Opportunities	**Threats**
- The region is a rapidly expanding touristic area; - The airport managing body has a great know-how as it manages several airports; - Expansion of the parking offer, including rental cars; - Rationalization of airport-station-port bus services; - A new "Flixbus" stop at the airport.	- Uncertain timing for the construction of the new highway tollbooth and dedicated roads; - Resistance on the part of transport operators towards an integrated tariff system and information; - Currently, the COVID emergency prevents the planning of business aviation.

‘A6’ Airport – SWOT analysis

Strengths	Weaknesses
- The tourist attractiveness of the region, and in particular the area served by the Airport, is constantly increasing; - Proximity to the city and its port; - There are no criticalities with the public administration and/or the local population of the nearby municipalities for noise, etc; - Presence of a direct and frequent bus connection between the airport, the railway station and the port; - Presence of direct and frequent bus connections with the nearby city.	- High parking occupancy rate; - Seasonality of the demand; - Traffic congestion on the access roads to the airport (in particular the arrivals area) in some time slots.
Opportunities	**Threats**
- Expansion of parking spaces; - Construction of the new railway connection with A6 Airport, which allows the offer of direct connections with the main regional destinations, in particular the regional capital, and nearby main cities; - A new Flixbus stop at the airport.	- Lack of funds to finance the enhancement of local public transport services.

Water management

At Adrigreen airports, water consumption ranged between 8,455 and 88,799 m3 and from 12.3 to 34.4 l/passenger. The l/passenger index is commonly used for evaluating water consumption, but it may not reflect conservation actions or the best management of water resources in a specific airport (de Castro Carvalho et al. 2013).

To reduce the water footprint of the airport infrastructures, the Adrigreen partners reported to have in place initiatives aiming at reducing water consumption, monitoring the quality of surface water and groundwater and preventing groundwater pollution.

The reduction in water consumption would result in decreasing greenhouse gases emissions deriving from water management. For example, in Italy the consumption of one m3 of drinking water corresponds to the emission of 0.579kg CO_2eq (Dominici Loprieno et al. 2017). Figure 2 shows the budgets of greenhouse gases emissions deriving from airports' yearly mean water consumption compared to the overall mean water consumption of the Adrigreen airports.

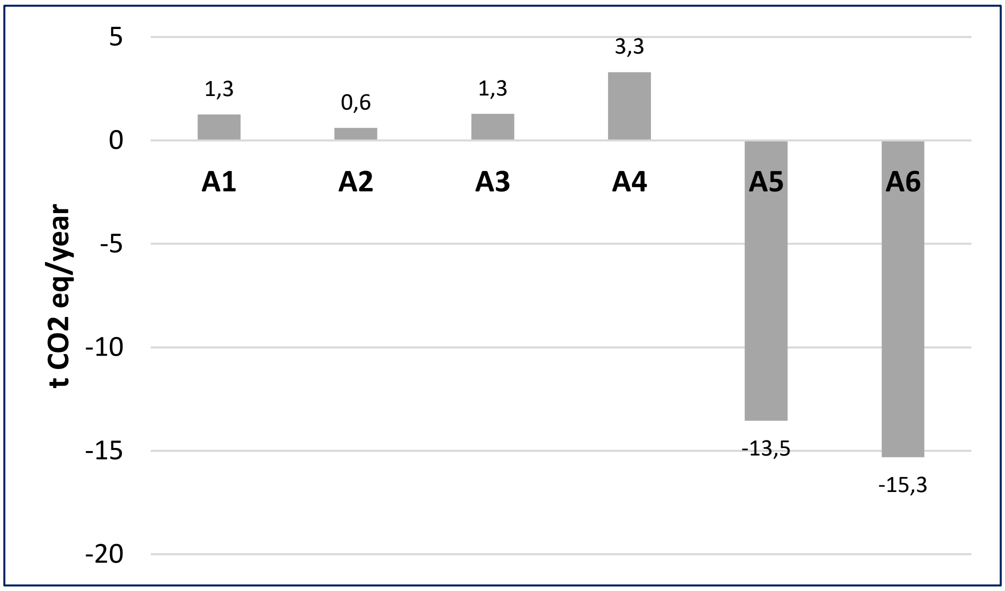


Figure 2 Disparities in greenhouse gases emissions deriving from the difference between airports' yearly mean and overall mean water consumption per passenger in the time period 2016 – 2018.

Mean water consumption between 2.5 and 3.7l/passenger above the overall mean corresponds up to 3.3t CO_2eq higher greenhouse gases emissions each year, whereas mean water consumption about

11l/passenger below the overall mean corresponds to about 15.3t CO2eq lower greenhouse gases emissions each year.

Table 4 resumes examples of actions aimed at reducing the water footprint of the airport infrastructure. For further information about sustainable airport water management, the readers can refer to the comprehensive work by Baxter et al. (2019).

General action	Specific Short-Term Long-Term Action	Metrics	Applicable to	Status	Strengths Weaknesses (Index)	Opportunities Threats (Index)
Decreasing water consumption	Monitoring of water consumption (STA)	Water consumption (m3, l/passenger)	A1	2	1	1
			A2	2	1	-1
			A3	2	1	0
			A4	2	N/A	N/A
			A5	2	1	1
			A6	2	2	1
Decreasing drinking water consumption	Rainwater harvest and use (LTA)	Water consumption (m3, l/passenger)	A1	1	2	1
			A2	1	1	-1
			A3	1	1	0
			A4	1	N/A	N/A
			A5	3	N/A	N/A
			A6	3	N/A	N/A
Reducing the water pollution	Surface water and groundwater quality monitoring (STA)	Water quality criteria	A1	3	N/A	N/A
			A2	1	1	-1
			A3	1	2	0
			A4	3	N/A	N/A
			A5	3	N/A	N/A
			A6	3	N/A	N/A
Reducing the water footprint	Organize training and education of airport staff (STA)	Participants' satisfaction	A1	2	1	0
			A2	2	1	0
			A3	2	0	0
			A4	2	N/A	N/A
			A5	2	1	2
			A6	2	2	0
N/A = not applicable; LTA = long term action; STA = short term action						

Table 4 Status and applicability of actions to reduce the water footprint of the airport infrastructure and potential indicators.

Figure 3, Figure 4, and Figure 5 show a comparison between airports' yearly mean and overall mean water consumption in terms of budget respectively for the minimum (2.4€/m3), mean (3.0€/m3), and maximum (3.8€/m3) unit cost of water for Adrigreen airports.

Considering the overall mean cost of about 3.0€/m3, airports' yearly mean water consumption up to 3.7l/passenger above the overall mean corresponds to spending up to 16,950€ more, whereas airports' yearly mean water consumption up to 11.3l/passenger below the overall mean leads to savings up to 78,500€ each year.

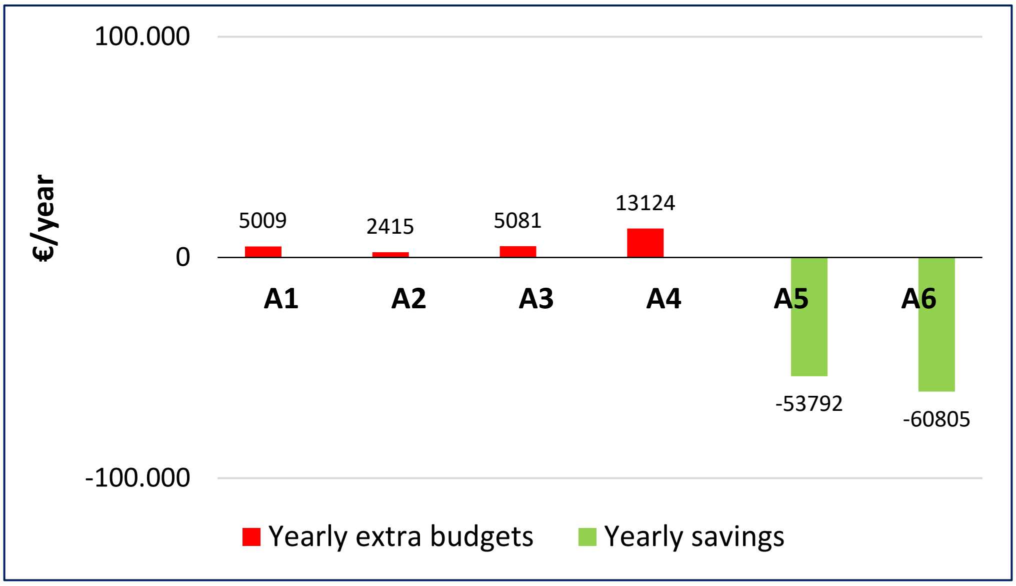


Figure 3 Yearly savings/extra budgets deriving from water consumption below/above the Adrigreen airports' average based on Adrigreen airports' overall minimum cost of water (2.4€/m3) in the time period 2016–2018.

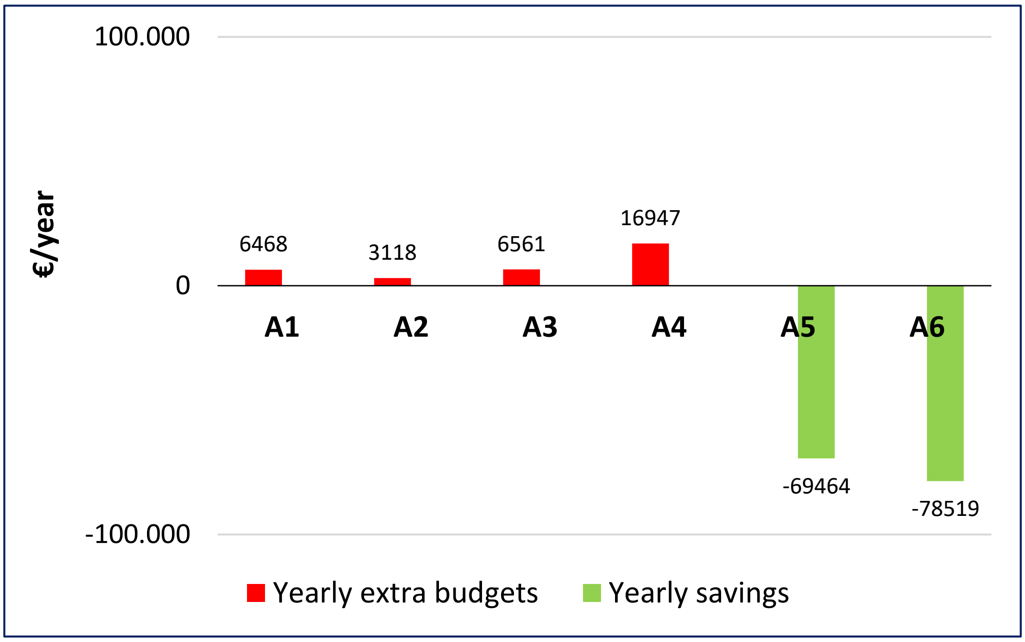


Figure 4 Yearly savings/extra budgets deriving from water consumption below/above the Adrigreen airports' average based on Adrigreen airports' overall mean cost of water (3.0€/m3) in the time period 2016–2018.

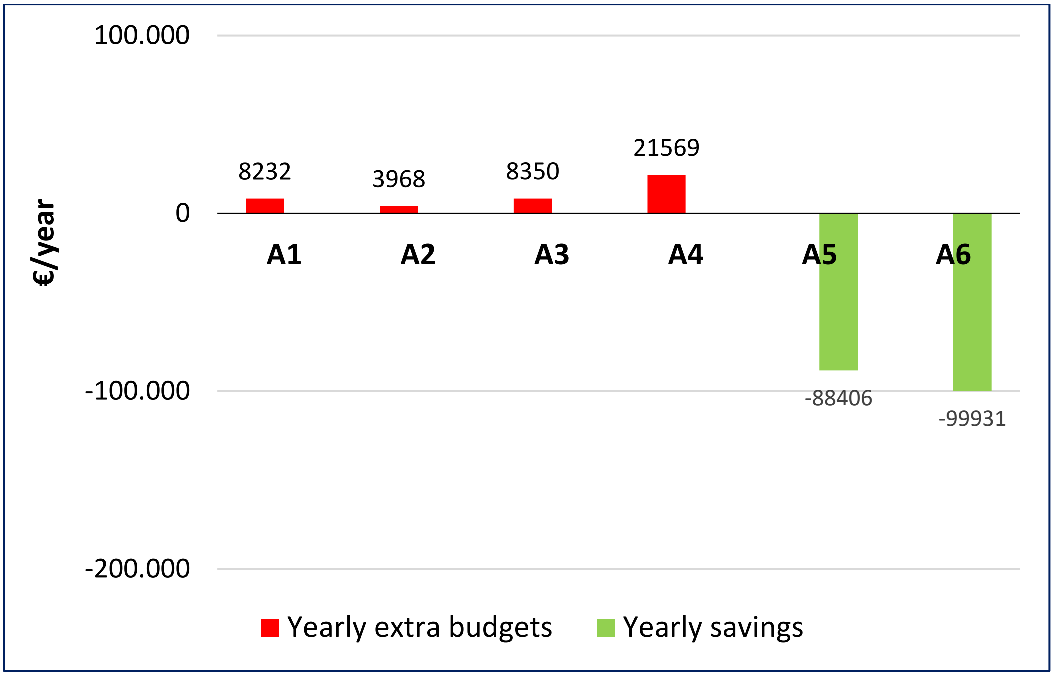


Figure 5 Yearly savings/extra budgets deriving from water consumption below/above the Adrigreen airports' average based on Adrigreen airports' overall maximum cost of water (3.8€/m3) in the time period 2016–2018.

Table 5 resumes relevant airport reference case studies for actions aimed at reducing the water footprint.

General action	Specific action	Metrics	Airport reference case studies
Decreasing water consumption	Monitoring for water consumption and leaks	Water consumption (m3, l/passenger)	Manchester Airport, London Heathrow International Airport (De Castro Carvalho et al. 2013).
Decreasing drinking water consumption	Rainwater harvest and use	Water consumption (m3, l/passenger)	A5, and A6 airports (this study); Boston Logan International Airport (Massport 2018); Website of Delhi Airport (2021).
Reducing the water pollution	Surface water and groundwater quality monitoring	Water quality criteria	A1, A4, A5, and A6 airports (this study); Copenhagen Airport (Baxter et al. 2019).
Reducing the water footprint	Organize training and education of airport staff	Participants' satisfaction	Website of Airports International Council.

Table 5 Airport reference case studies for actions aimed at reducing the water footprint.

Waste management

Regarding waste handling at Adrigreen airports, A4, A5, and A6 recycle different types of waste fractions (e.g., paper and cardboard, metal, plastic, glass, organic fraction and hazardous waste), whereas A1, A2, and A3 airports recycle only paper, cardboard, and metal.

In line with the so-called "waste hierarchy", waste management initiatives promote waste prevention, reduction, recycling, and recovery with the aim of achieving the goal of sending zero waste to landfills.

Reducing the amount of waste sent to landfills has also an impact on global climate change in terms of reduction in greenhouse gases emissions. For example, each kilogram of general waste stockpiled in landfills leads to the emission of up to one kilogram of CO2eq (Oficina Catalana del Canvi Climàtic 2019).

A waste metric, that is useful to evaluate the efficiency of waste recycling actions, is the percentage diversion rate (ICAO-b):

$$Diversion\ rate = \frac{R}{R+W} \times 100\ [\%]$$

where *R* is the weight of recycled materials that are separated from the general waste and *W* is the weight of the unsorted-fraction of general waste.

ICAO (–a) reported a set of successful eco-friendly waste management initiatives implemented at different airports around the globe including some European airports.

Table 6 summarizes several examples of actions aimed at sustainable waste-management within airport infrastructures.

General action	Specific Short-Term Long-Term Action	Metrics	Applicable to	Status	Strengths Weaknesses (Index)	Opportunities Threats (Index)
Promoting waste prevention and recycling	Economic incentives for recycling more and generating less waste (e.g., the pay-as-you-throw program) (STA)	tons of waste fractions/year	A1	1	2	2
			A2	1	0	1
			A3	1	-1	1
			A4	1	N/A	N/A
			A5	1	1	2
			A6	1	1	1
Waste prevention	Disposable plastic cutlery and beverages replaced with easily degradable materials (STA)	kg plastic waste/passenger	A1	3	N/A	N/A
			A2	1	0	1
			A3	1	0	1
			A4	1	N/A	N/A
			A5	1	1	2
			A6	1	2	1
Promoting waste recycling	Training of employees on recycling (STA)	tons of waste fractions/year	A1	1	1	1
			A2	1	0	1
			A3	1	2	0
			A4	1	N/A	N/A
			A5	3	N/A	N/A
			A6	3	N/A	N/A
Promoting waste recycling	Instructions for waste separation at the passenger terminal (STA)	kg/passenger	A1	3	N/A	N/A
			A2	1	0	1
			A3	1	1	2
			A4	1	N/A	N/A
			A5	3	N/A	N/A
			A6	3	N/A	N/A
Promoting waste reuse	Use construction waste and amend construction standards to reflect best practice in material reuse (LTA)	tons of waste	A1	1	2	0
			A2	1	-1	-1
			A3	1	0	1
			A4	1	N/A	N/A
			A5	1	0	1
			A6	1	0	1
Promoting waste reuse	Use of environmentally friendly asphalt for repaving parking lots and runways (LTA)	tons of recycled asphalt; emissions of GHG and airborne pollutants	A1	1	1	0
			A2	1	2	0
			A3	1	2	0
			A4	1	N/A	N/A
			A5	1	2	2
			A6	1	2	1
GHG = Greenhouse Gases ;N/A = Not Applicable; LTA = Long Term Action; STA = Short Term Action						

Table 6 Status and applicability of actions related to waste management and potential indicators.

Table 7 resumes relevant reference case studies for actions aimed at improving waste management at the airport infrastructure.

General action	Specific action	Metrics	Airport reference case studies
Promoting waste prevention and recycling	Economic incentives for recycling more and generating less waste (e.g., the pay-as-you-throw program)	tons of waste fractions/year	London Stansted Airport (2010).
Waste prevention	Disposable plastic cutlery and beverages replaced with easily degradable materials	kg plastic waste/passenger	A1 airport (this study); Glasgow Airport (2019).
Promoting waste recycling	Training of employees on recycling	tons of waste fractions/year; participants' satisfaction	A5, and A6 airports (this study); London Stansted Airport (2010); Website of Airports International Council.
Promoting waste recycling	Instructions for waste separation at the passenger terminal	kg/passenger	A1, A5, and A6 airports (this study).
Promoting waste reuse	Use construction waste and amend construction standards to reflect best practice in material reuse	tons of waste	London Stansted Airport (2010).
Promoting waste reuse	Use of environmentally friendly asphalt for repaving parking lots and runways	tons of recycled asphalt; emissions of GHG and airborne pollutants	Hamburg, Frankfurt, Munich, and Cambridge Airports, (D'Angelo et al. 2008, White 2013); Logan International Airport (Civil + Structural Engineer, 2008).
GHG = Greenhouse Gases			

Table 7 Airport reference case studies for actions aimed at improving waste management.

Energy management

Terminals are responsible for the largest fraction of energy consumption at airports (ACI 2012). For example, at Santander Airport (Spain) the terminal building accounted for about 76.6% of the energy consumption of the entire infrastructure (Airport Seve Ballesteros-Santander cited by Ortega Alba and Manana 2016). Also for energy savings, the related environmental benefits are both in terms of climate-change global impacts and in terms of quality of the local environment.

At A1, A2, A3, and A4 airports, the fuel consumption for heating buildings was the second contributor to the greenhouse gases emissions deriving from energy consumption (from 21.7% up to 51.1%).

Adrigreen airports' greenhouse gases emissions deriving from the fuel used for heating buildings ranged from 0.1 to 2.1kg of CO_2eq/passenger and between 1 and 6kg of CO_2eq/m^3 of heated spaces.

Figure 6 shows the budgets in greenhouse gases emissions deriving from differences between airports' yearly mean and overall mean fuel consumption for heating the buildings at Adrigreen airports.

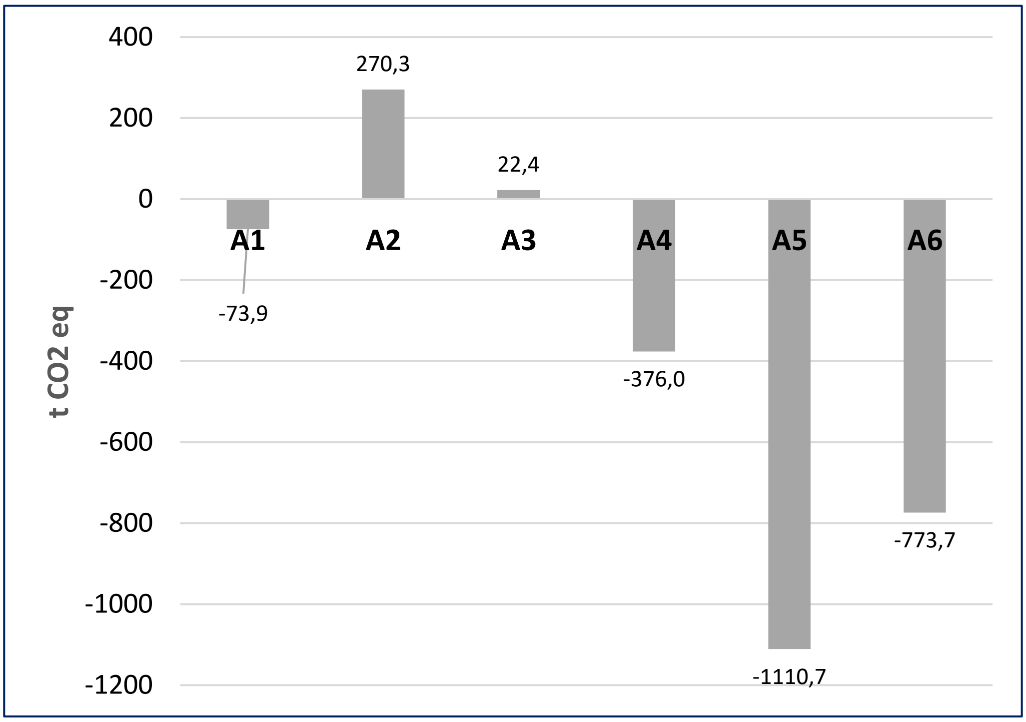


Figure 6 Disparities in greenhouse gases emissions related to the difference between airports' yearly mean and overall mean fuel consumption for heating buildings in the time period 2016–2018.

Greenhouse gases emissions deriving from mean fuel consumption up to 0.96kg CO_2eq/passenger above the overall mean can add up to 270t of CO_2eq emissions each year, whereas fuel consumption up to 0.33kg CO2 eq/passenger below the overall mean can decrease up to 1110t of CO2eq emissions each year.

Energy efficiency of terminal buildings and the related appliances varies with the technologies employed, the design and the age of the building (ACI 2012). Improving the energy efficiency is a prerequisite to reduce exhaust emissions deriving from the combustion of fuel for heating purposes.

Table 8 resumes examples of actions aimed at decreasing energy consumption at the airports.

General action	Specific Short-Term Long-Term Action	Metrics	Applicable to	Status	Strengths Weaknesses (Index)	Opportunities Threats (Index)
Decreasing energy consumption	Building Management System (STA)	Total energy consumed; electricity consumption (kWh); fuel consumption (m3; l; kg); GHG emissions (kg CO2eq/m3; kg CO2eq/passenger)	A1	1	1	1
			A2	1	2	1
			A3	3	N/A	N/A
			A4	1	N/A	N/A
			A5	1	0	1
			A6	1	1	0
Decreasing energy consumption	Cogeneration CHP/CCHP plant (LTA)	Total energy consumed; electricity consumption (kWh); fuel consumption (m3; l; kg); GHG emissions (kg CO2eq/m3; kg CO2eq/passenger)	A1	1	0	1
			A2	1	2	1
			A3	1	1	1
			A4	1	N/A	N/A
			A5	2	1	2
			A6	1	1	0
. GHG = Greenhouse Gases; N/A = Not Applicable; LTA = Long Term Action; STA = Short Term Action						

Table 8 Actions aimed at reducing energy consumption and potential indicators.

Table 9 summarizes relevant/reference case studies of actions aimed at decreasing energy consumption at the airports.

General measure	Specific action	Metrics	Airport reference case studies
Decreasing energy consumption	Building management system	Total energy consumed (electricity consumption (kWh); fuel consumption (m3; l; kg)); GHG emissions (kg CO2eq/m3; kg CO2eq/passenger)	A3 airport (this study).
Decreasing energy consumption	Cogeneration plant	Total energy consumed (electricity consumption (kWh); fuel consumption (m3; l; kg)); GHG emissions (kg CO2eq/m3; kg CO2eq/passenger)	Website of Leonardo da Vinci Airport (—); Malpensa Airport (SEA Energia 2019).
GHG = Greenhouse Gases.			

Table 9 Airport reference case studies for actions aimed at decreasing energy consumption.

Figure 7 shows a comparison between airports' yearly mean and overall mean fuel consumption for heating buildings in terms of budget based on the mean costs of diesel fuel (1.1€/l), heating oil (0.6€/l), and natural gas (0.64€/m3) for the Adrigreen airports.

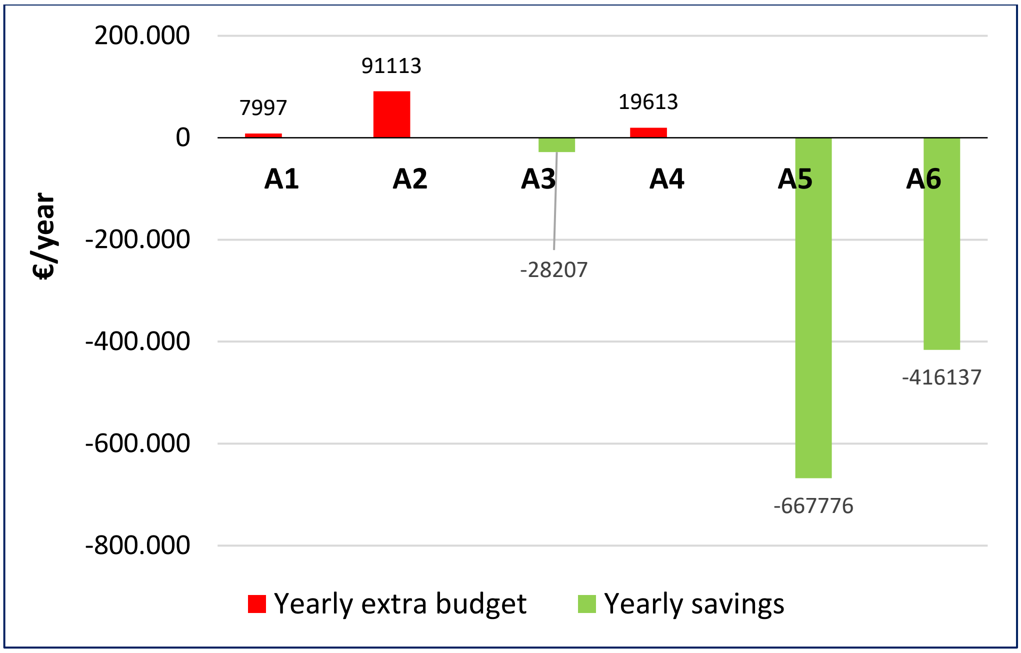


Figure 7 Disparities in budgets related to differences between airports' yearly mean and the overall mean fuel consumption for heating buildings based on the Adrigreen airports' overall mean cost of diesel fuel (1.1€/l), heating oil (0.6€/l), and natural gas (0.64€/m3) in the time period 2016–2018.

Figure 8 shows a comparison between airports' yearly mean and overall mean diesel fuel consumption for heating buildings in terms of budget. A2 Airport does not use diesel fuel for heating purposes. Considering the overall mean cost of about 1.1€/l, airports' yearly mean diesel fuel consumption up to 0.04l/passenger above the overall mean corresponds to extra costs up to 12,200€, whereas airports' yearly mean diesel fuel consumption up to 0.04l/passenger below the overall mean corresponds to extra savings up to 111,900€ each year.

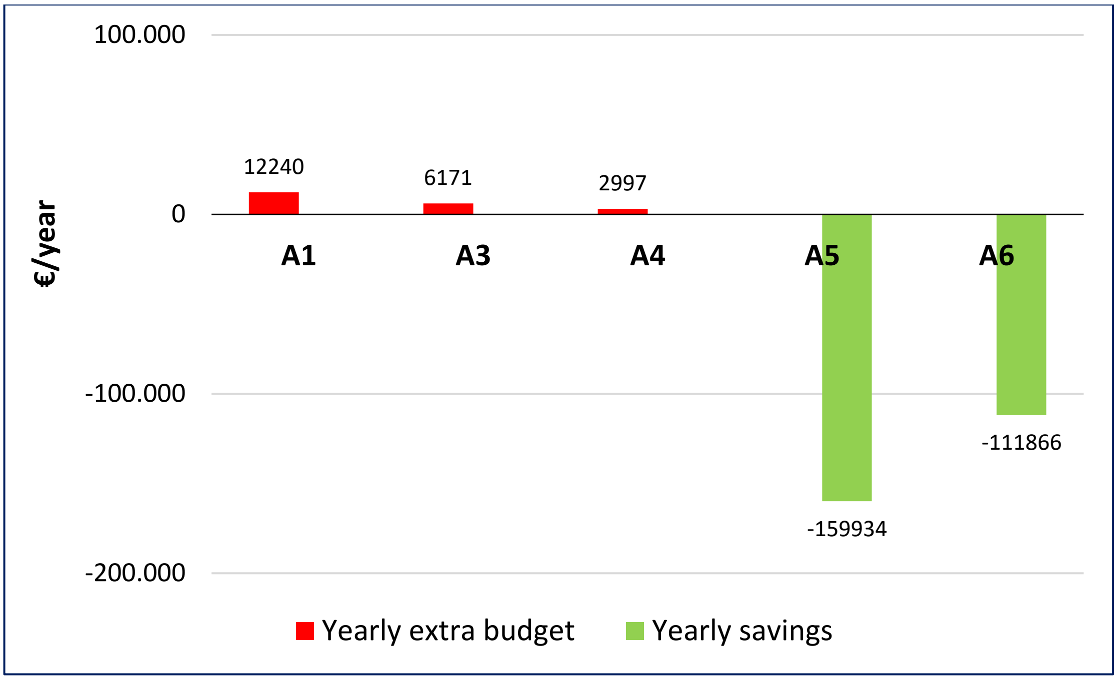


Figure 8 Disparities in budgets related to differences between airports' yearly mean and the overall mean diesel fuel consumption for heating buildings. Amounts are based on Adrigreen airports' overall mean cost of diesel fuel (1.1€/l) in the time period 2016–2018.

Figure 9 shows a comparison between airports' yearly mean and overall mean heating oil consumption for heating buildings in terms of budget. Only A1 and A4 airports reported to use heating oil for heating purposes. Considering the overall mean cost of about 0.6€/l, airports' yearly mean heating oil consumption up to 0.01l/passenger above the overall mean corresponds to extra costs up to 16,600€, whereas airports' yearly mean diesel fuel consumption up to 0.01l/passenger below the overall mean corresponds to extra savings up to 4,200€ each year.

As a special point, we must stress here that the use of diesel fuel for heating is strongly discouraged nowadays both for its rather high carbon footprint and for the relevant emissions of airborne pollutants associated to its use. Even more important, the use of heating oil is nowadays almost banned and should be discontinued being the related effects on the environment even more relevant. We strongly recommend Adrigreen partners to modify heating systems so to burn natural gas or, at least, liquified petroleum gas (LPG) or diesel fuel as soon as possible.

Figure 10 shows a comparison between airports' yearly mean and overall mean natural gas consumption for heating buildings in terms of budget. Only A1 and A4 airports do not use natural gas for heating purposes. Considering the overall mean cost of about 0.64€/m3, airports' yearly mean natural gas consumption up to 0.5m3/passenger above the overall mean corresponds to extra costs up to 91,100€, whereas airports' yearly mean natural gas consumption up to 0.2m3/passenger below the overall mean corresponds to extra savings up to 507,800€ each year (Figure 10).

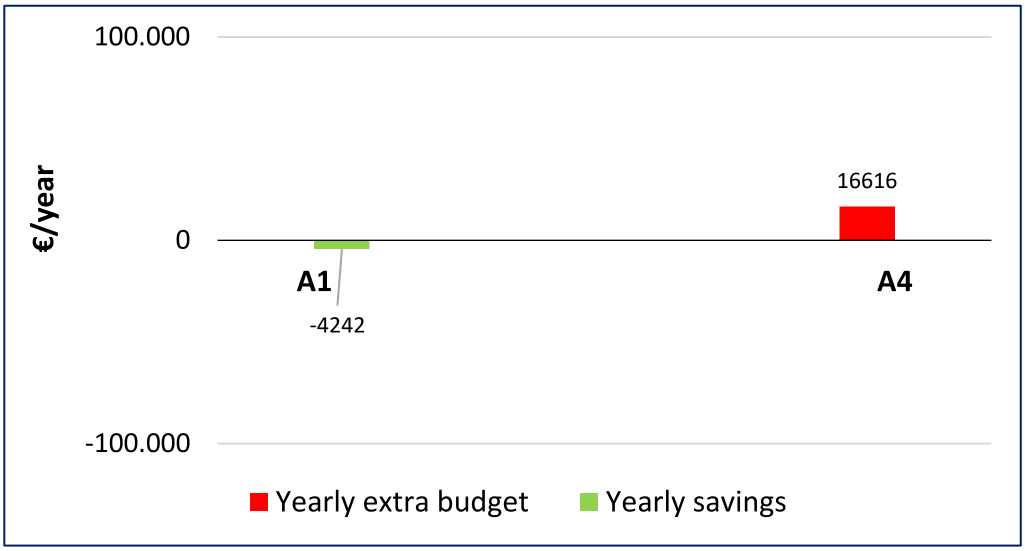


Figure 9 Disparities in budgets related to differences between airports' yearly mean and the overall mean heating oil consumption for heating buildings. Amounts are based on Adrigreen airports' overall mean cost of heating oil (0.6€/l). Time range is 2016–2018.

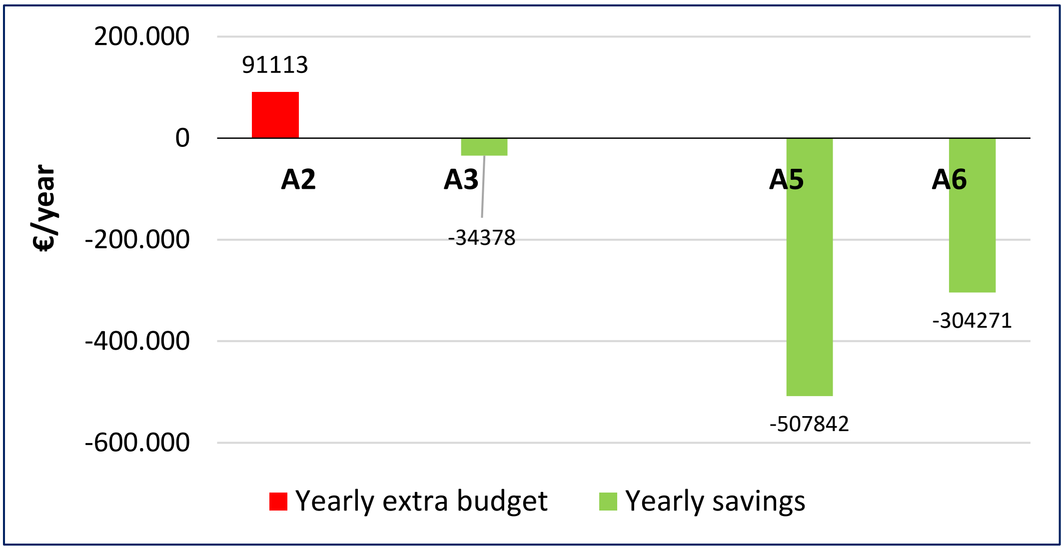


Figure 10 Disparities in budgets related to differences between airports' yearly mean and the overall mean heating oil consumption for heating buildings. Amounts are based on Adrigreen airports' overall mean cost of natural gas (0.64€/m3) in the time period 2016–2018.

Electricity

In line with the findings reported, between all, by Ortega Alba and Manana (2016), at Adrigreen airports electricity is the dominant energy supplier. In general, the electricity is delivered by the commercial grid and it is supplied by a power company at each Adrigreen airport. As a result, the highest fraction of the carbon footprint deriving from energy consumption is related to electricity. For example, at A1, A2, A3, and A4 airports, electricity consumption was the highest contributor to greenhouse gases emissions (from 43.8% up to 65.4%).

Figure 11 shows differences in greenhouse gases emissions deriving from airports' yearly mean electricity consumption compared with the overall mean electricity consumption of the Adrigreen airports. Mean electricity consumption up to 2.3kWh/passenger above the overall mean corresponds up to 223.3t of CO2eq extra emissions each year, whereas electricity consumption between 0.4–0.6kWh/passenger below the overall mean corresponds to 94.3–518.9t of CO2eq lower emissions each year.

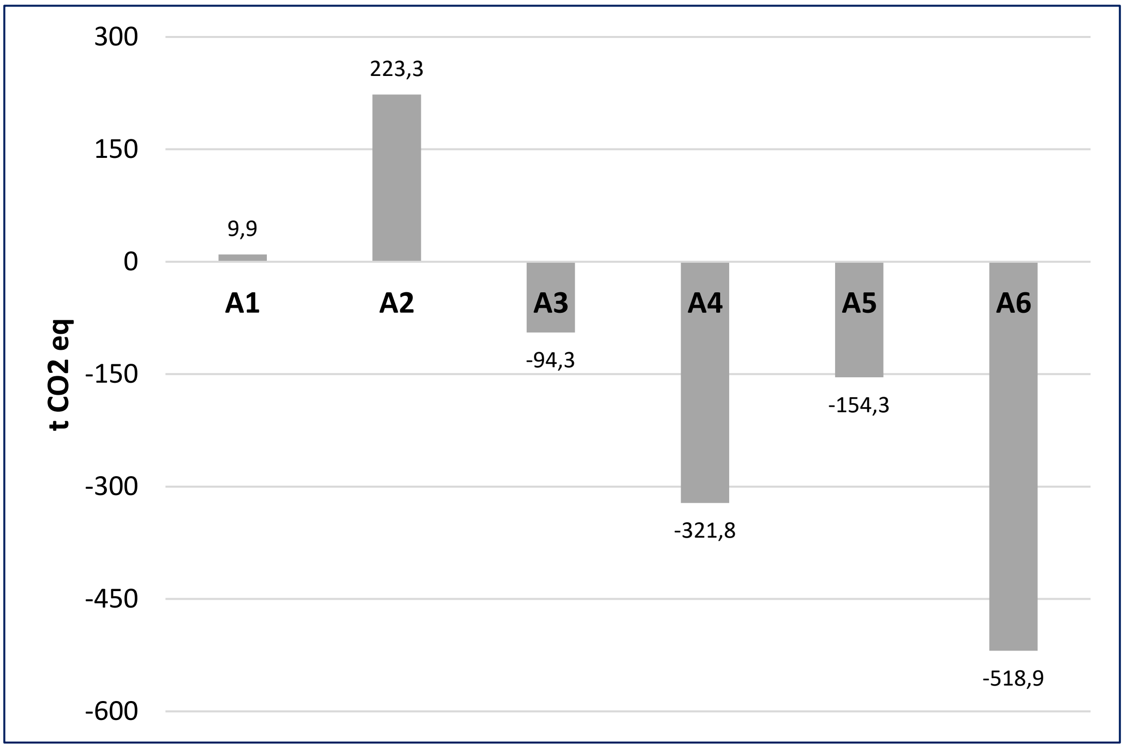


Figure 11 Departures in greenhouse gases emissions related to the difference between airports' yearly mean and overall mean electricity consumption in the time period 2016 – 2018.

The action plans aimed at reducing electricity consumption first would have an impact on the total energy consumption of the airports. These actions would result also in decreasing the carbon footprint of the airport activities. For example, Light-Emitting Diodes (LED) lightning has been already implemented by most of the Adrigreen partners as an action to reduce electricity consumption and hence decrease greenhouse gases emissions. The complete transition to LED lighting system could represent an interesting option.

Even without decreasing electricity absorption, action plans aimed at decarbonizing electricity consumption would decrease the carbon footprint of the airport activities too. For example, at Adrigreen airports part of the electricity consumed is already produced or is going to be produced through on-site renewable energy generation (e.g. photovoltaic systems) or “renewable-like” energy generation (e.g. Combined Heat and Power or Combined Cooling, Heat and Power plants). In terms of carbon footprint, the environmental assessments of A5 and A6 airports showed the best results because of green power purchasing (i.e., electricity generated from renewable resources such as solar, wind, geothermal, hydropower, etc.) coupled with local photovoltaic systems.

According to a survey reported by the European Environment Agency (2019), 65% of the airports reported to purchase electricity from renewable sources. Moreover, on-site renewable energy generation is done at 61% of the airports that took part to the survey (European Environment Agency 2019), with the renewable energy produced on site covering 1–20% of the energy needs of 89% of these airports.

Table 10 reports examples of actions aimed at reducing the electricity consumption and/or the related carbon footprint.

General action	Specific Short-Term Long-Term Action	Metrics	Applicable to	Status	Strengths Weaknesses (Index)	Opportunities Threats (Index)
Decreasing electricity consumption	Light-Emitting Diodes (LED) lightning (STA)	Electricity consumption (kWh); GHG emissions (CO2eq)	A1	2	0	1
			A2	2	1	1
			A3	2	1	0
			A4	2	N/A	N/A
			A5	2	0	1
			A6	2	-1	1
Decarbonizing electricity consumption	On-site renewable energy generation (LTA)	Electricity consumption (kWh) from the commercial grid; GHG emissions (CO2eq)	A1	1	2	0
			A2	1	1	1
			A3	1	1	1
			A4	1	N/A	N/A
			A5	1	0	2
			A6	1	2	0
Decarbonizing electricity consumption	Solar energy to power aircrafts at the gate (LTA)	Electricity consumption (kWh) vs fuel consumption (l); GHG emissions and airborne pollutants emissions	A1	1	2	0
			A2	1	1	1
			A3	1	1	1
			A4	1	N/A	N/A
			A5	1	0	2
			A6	1	2	0
Decarbonizing electricity consumption	Purchase of electricity generated from a mix of renewable energy sources (STA)	GHG emissions (CO2eq); Amount of renewable energy purchased by the airport, as a percentage of total energy consumed by the airport (ACI 2012)	A1	1	-1	0
			A2	1	1	1
			A3	1	1	1
			A4	1	N/A	N/A
			A5	3	N/A	N/A
			A6	3	N/A	N/A
GHG = Greenhouse Gases; N/A – Not Applicable; LTA = Long Term Action; STA = Short Term Action						

Table 10 Actions related to electricity consumption and potential indicators.

Figure 12, Figure 13, and Figure 14 show a comparison between Adrigreen airports' yearly mean and overall mean electricity consumption in terms of budget. Figure 12 takes into account the electricity lower price (0.13€/kWh), Figure 13 the average price (0.15€/kWh), and Figure 14 the top price (0.16€/kWh) for the various airports. Considering the overall mean price of about 0.15€/kWh, airports' yearly mean electricity consumption up to 2.3kWh/passenger above the overall mean corresponds to extra costs up to 101,000€, whereas airports' yearly mean electricity consumption up to 0.6kWh/passenger below the overall mean leads to extra savings up to 235,000€ each year.

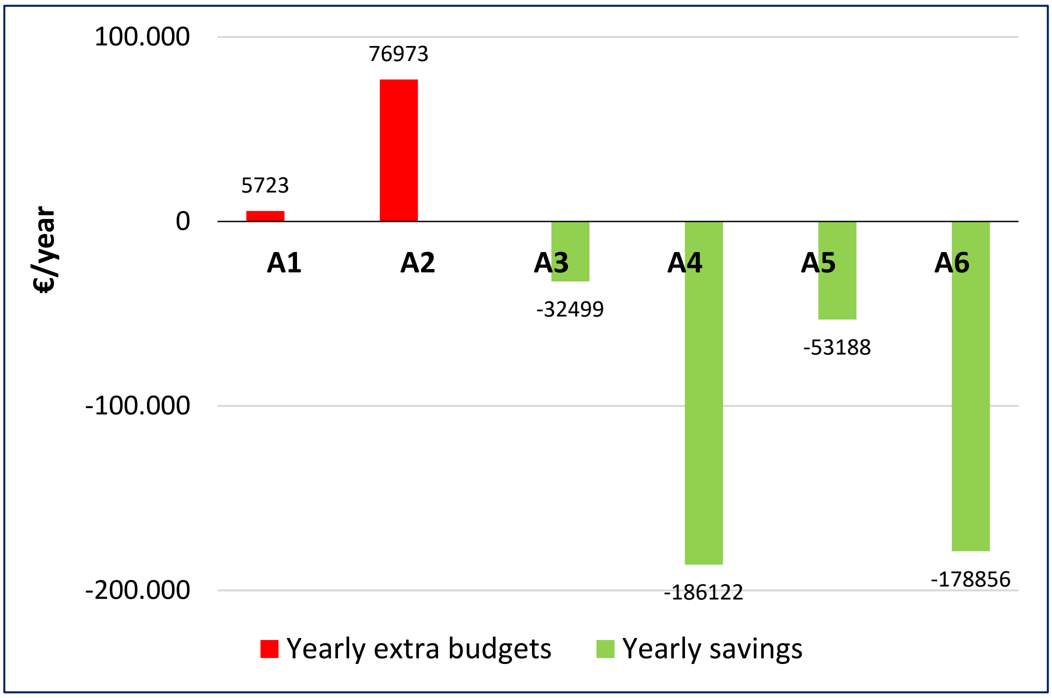


Figure 12 Yearly savings/extra costs deriving from electricity consumption below/above the Adrigreen airports' consumption benchmark based on Adrigreen airports' overall minimum price (0.13€/kWh) in the time period 2016–2018.

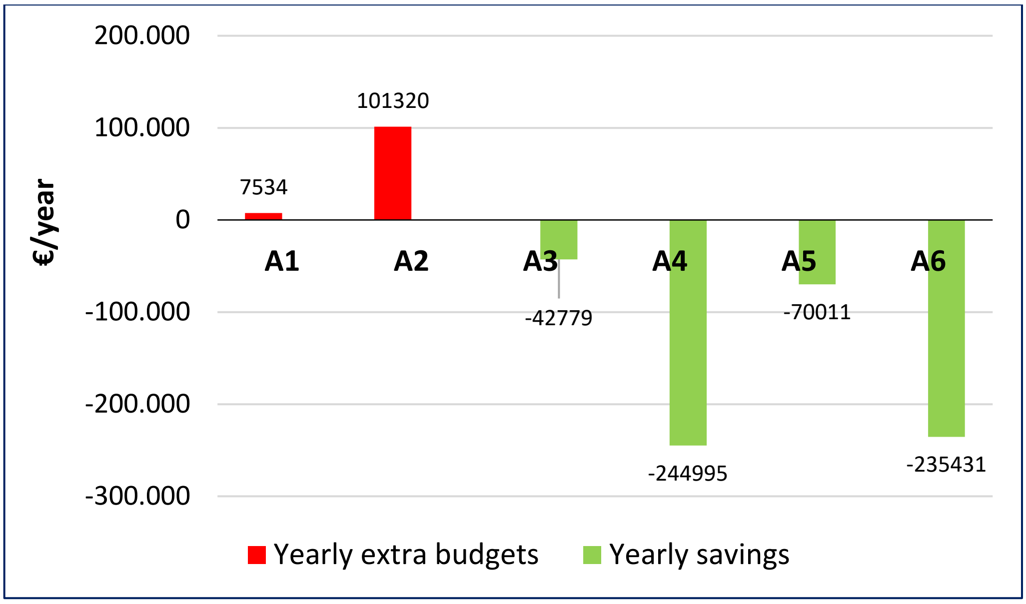


Figure 13 Yearly savings/extra costs deriving from electricity consumption below/above the Adrigreen airports' consumption benchmark based on Adrigreen airports' overall mean price (0.15€/kWh) in the time period 2016–2018.

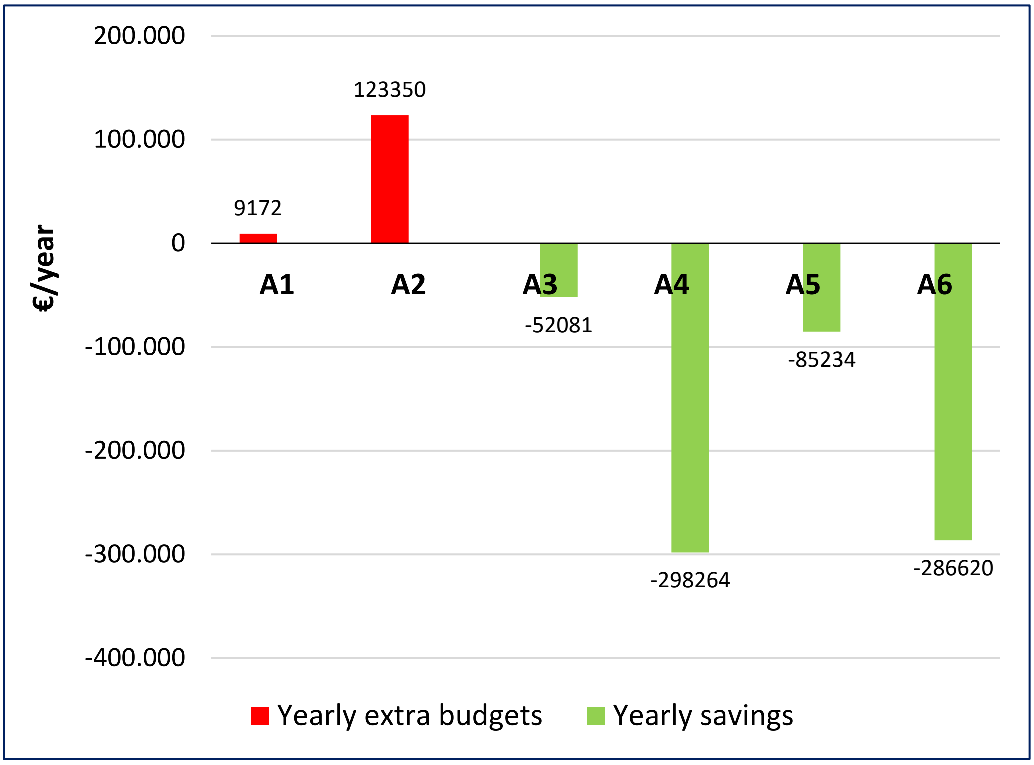


Figure 14 Yearly savings/extra costs deriving from electricity consumption below/above the Adrigreen airports' consumption benchmark based on Adrigreen airports' overall maximum price (0.16€/kWh) in the time period 2016–2018.

Table 11 summarizes relevant/reference case studies of actions aimed at decreasing the environmental footprint of electricity consumption at the airports.

General action	Specific action	Metrics	Airport reference case studies
Decreasing electricity consumption	Light-emitting diodes (LED) lightning	Electricity consumption (kWh); GHG emissions (CO2eq)	Copenhagen Airport (Baxter, et al. 2018).
Decarbonizing electricity consumption	On-site renewable energy generation	Electricity consumption (kWh) from the commercial grid; GHG emissions (CO2eq)	A4, A5, and A6 airports (this study); Copenhagen Airport (Baxter, et al. 2018); Paris Airport, and Stockholm-Arlanda Airport ICAO (—c).
Decarbonizing electricity consumption	Solar energy to power aircrafts at the gate	Electricity consumption (kWh) vs fuel consumption (l); GHG emissions (CO2eq) and airborne pollutants emissions	Douala International Airport (ICAO —d).
Decarbonizing electricity consumption	Purchase of electricity generated from a mix of renewable energy sources	GHG emissions (CO2eq); Amount of renewable energy purchased by the airport, as a percentage of total energy consumed by the airport (ACI 2012)	A5, and A6 airports (this study).
GHG = Greenhouse Gases			

Table 11 Airport reference case studies for actions aimed at decreasing the environmental footprint of electricity consumption.

Fossil fuel consumption of company operated vehicles

Fossil-fuel vehicles generate negative impacts both on the global scale and on the local environments. The framework is the same that we have already outlined for heating fuels but here the effects are even bigger, especially in terms of local airborne pollutant emissions.

Adrigreen airports' greenhouse gases emissions deriving from the operations performed by fossil fuel vehicles were up to 0.3kg CO_2/passenger. For example, each kilogram of fuel consumed by diesel or petrol passenger cars corresponds to the emission of more than 3kg of CO_2 (Ntziachristos et al. 2019). Moreover, as already outlined, several more toxic substances are poured into the environment, manly airborne pollutants deriving both from the combustion and from the wearing of brake pads, tires, etc. While there is currently no way to reduce the latter, the former can be significantly reduced or even zeroed by introducing modern technologies such as electrification.

Figure 15 shows disparities in greenhouse gases emissions deriving from differences between airports' yearly mean and overall mean fuel consumption for company operated vehicles of the Adrigreen airports.

Greenhouse gases emissions deriving from mean fuel consumption up to 0.17kg of CO_2eq per passenger above the overall mean corresponds up to 395t of extra CO_2eq emissions each year, whereas fuel consumption up to 0.16kg of CO_2eq per passenger below the overall mean leads to a reduction up to 717t of CO_2eq emissions each year.

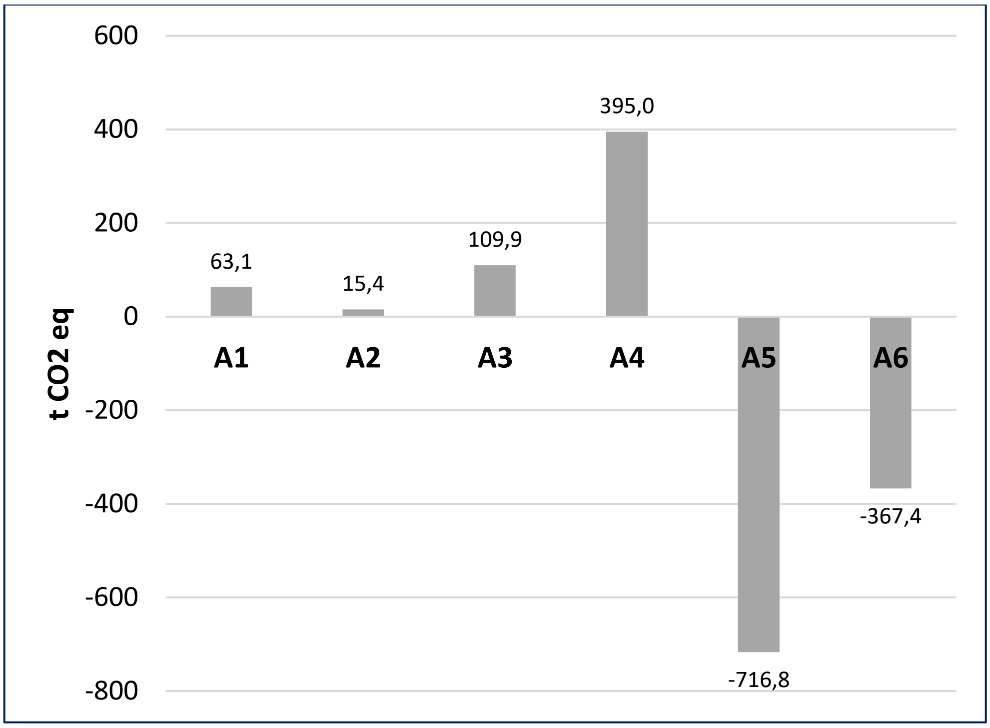


Figure 15 Disparities in greenhouse gases emissions related to the difference between airports' yearly mean and overall mean fuel consumption for company operated vehicles in the time period 2016 –2018.

A potential distortion in the benchmarking of the fossil fuel consumption of vehicles managed by Adrigreen partners could arise when comparing airports implementing partial/total outsourcing of airside service with airports operating fully-internal facilities.

As already outlined, fossil fuel vehicles impair the condition of the ambient air in the vicinity of the airports. For instance, diesel passenger cars release about 13g of nitrogen oxides and more than 1g of particulate matter per each kilogram of fuel they burn (Ntziachristos et al. 2019). Switching from fossil-fuel to electric vehicles would result in decreasing local emissions of airborne pollutants.

Besides the arguments outlined at the beginning of this chapter, local emissions of some airborne pollutants such as NOx and fine particulate matter can be assumed nil for the electric vehicles. However, the emission of some pollutants, especially greenhouse gases should be taken into account depending on the production site and on the technology operated for producing electricity. For example, greenhouse gases are released during the generation of electricity in power plants that burn fossil fuels and these emissions must be taken into account. Also, one may generate electricity locally, for instance by a Combined Heating Cooling and Power generator. In this case, also airborne pollutant emissions are to be taken into account.

According to a survey reported by the European Environment Agency (2019), the purchase of electric vehicles is the most popular mitigation action to contain the environmental impact of the airports' vehicle fleet (Table 12).

	Share of (51) EU28 European Free Trade Association airports [%]
Electric vehicles	86
Hybrid vehicles	47
Vehicles that run on sustainable alternative fuel	35
Provide incentives for taxis that use ‘green’ vehicle solutions	18

Table 12 Share of (51) EU28 and European Free Trade Association airports implementing environmental impact mitigation actions related to vehicle fleet.

Table 13 (adapted from European Environment Agency 2019) shows some actions that may apply to the Adrigreen partners for the decrease/decarbonization of fossil fuel consumption of company-operated vehicles.

General action	Specific Short-Term Long-Term Action	Metrics	Applicable to	Status	Strengths Weaknesses (Index)	Opportunities Threats (Index)
Decreasing fossil fuel consumption	Purchase of electric vehicles (e.g., electric aircraft tug, electric baggage tractor, etc.) (STA)	Electricity consumption (kWh) versus kg or l fossil fuel; GHG emissions (CO2eq)	A1	2	0	1
			A2	1	1	1
			A3	2	2	2
			A4	2	N/A	N/A
			A5	1	0	2
			A6	1	-1	0
Decreasing fossil fuel consumption	Provide charging stations for electric vehicles (STA)	Electricity consumption (kW); GHG and airborne pollutants emissions	A1	3	N/A	N/A
			A2	1	1	2
			A3	2	2	1
			A4	2	N/A	N/A
			A5	2	1	1
			A6	2	-2	0
Decreasing fossil fuel consumption	Anti-idling communication campaign (STA)	GHG and airborne pollutants emissions	A1	1	1	1
			A2	1	2	2
			A3	1	1	0
			A4	1	N/A	N/A
			A5	1	2	1
			A6	1	2	1
Decarbonizing fuel consumption	Use of alternative renewable fuels (diesel from waste and residue) for diesel vehicles (STA)	Consumption of renewable fuel vs fossil fuel (l); GHG emissions	A1	1	1	0
			A2	1	1	1
			A3	1	1	2
			A4	1	N/A	N/A
			A5	1	0	1
			A6	1	0	0
GHG = Greenhouse Gases; N/A = Not Applicable; LTA = Long Term Action; STA = Short Term Action						

Table 13 Status and applicability of actions related to decrease/decarbonize fossil fuel consumption of company operated vehicles and potential indicators.

Figure 16 shows a comparison between airports' yearly mean and overall mean fuel consumption for company operated vehicles in terms of budget based on the mean costs of diesel fuel (1.12€/l), and gasoline (1.23€/l) for the Adrigreen airports.

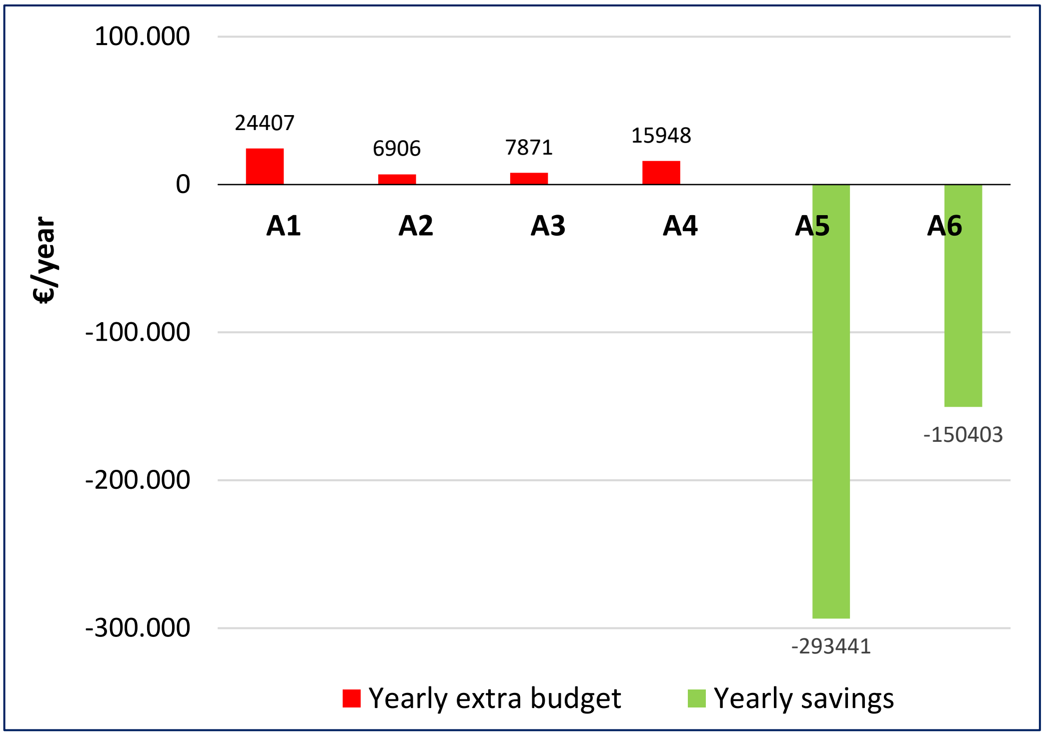


Figure 16 Disparities in budgets related to differences between airports' yearly mean and the overall mean fuel (diesel and petrol) consumption for company operated vehicles based on the Adrigreen airports' overall mean cost of diesel (1.12 €/l), and petrol (1.23 €/l) in the time period 2016–2018.

Figure 17 shows a comparison between airports' yearly mean and overall mean diesel fuel consumption for company operated vehicles in terms of budget.

Considering the overall mean cost of about 1.12€/l, airports' yearly mean diesel fuel consumption up to 0.04l/passenger above the overall mean leads to extra costs up to 26,700€, whereas airports' yearly mean diesel fuel consumption up to 0.06l/passenger below the overall mean leads to savings up to 293,400€ each year.

Figure 18 shows a comparison between A1 and A4 airports' yearly mean and overall mean gasoline consumption for company-operated vehicles in terms of budget.

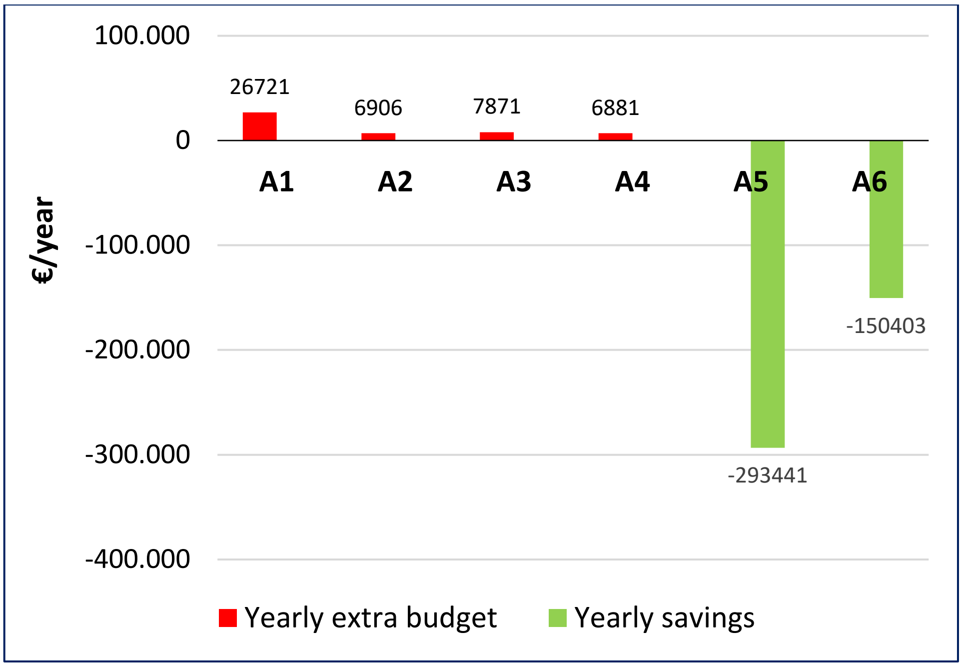


Figure 17 Yearly savings/extra costs deriving from company operated vehicles diesel fuel consumption below/above the Adrigreen airports' consumption benchmark based on Adrigreen airports' overall mean cost of diesel fuel (1.12€/l) in the time period 2016–2018.

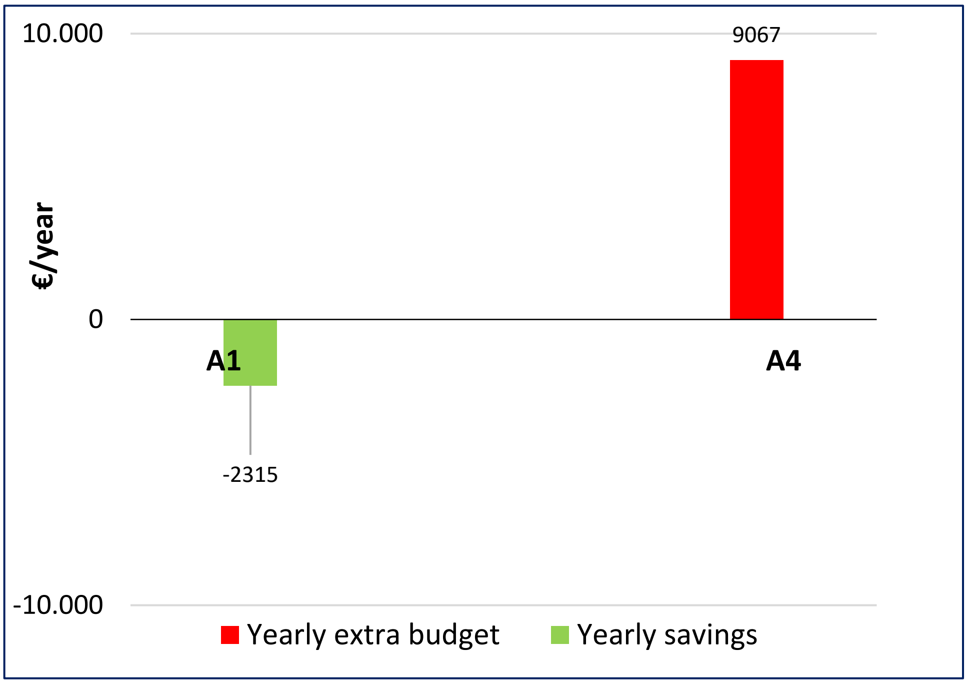


Figure 18 Yearly savings/extra costs deriving from company-operated vehicles gasoline consumption below/above the Adrigreen airports' consumption benchmark based on Adrigreen airports' overall mean cost of gasoline (1.23€/l) in the time period 2016–2018.

Table 14 summarizes relevant airport reference case studies for actions aimed at decreasing fossil fuel consumption at the airports.

General action	Specific action	Metrics	Airport reference case studies
Decreasing fossil fuel consumption	Purchase of electric vehicles (e.g., electric aircraft tug, electric baggage tractor, etc.)	Electricity consumption (kWh) versus kg or l of fossil fuel; GHG emissions (CO2eq)	Copenhagen Airport (2018).
Decreasing fossil fuel consumption	Provide charging stations for electric vehicles	Electricity consumption (kW); GHG and airborne pollutants emissions	A1 airport (this study); Helsinki Airport (Finavia 2019).
Decreasing fossil fuel consumption	Anti-idling communication campaign	GHG and airborne pollutants emissions	Copenhagen Airport (2018).
Decarbonizing fuel consumption	Use of alternative renewable fuels (diesel from waste and residue) for diesel vehicles	Consumption of renewable fuel vs fossil fuel (l); GHG emissions (CO2eq)	Helsinki Airport, and other Lapland Airports (Finavia 2018).
GHG = Greenhouse Gases			

Table 14 Airport reference case studies for actions aimed at decreasing the fossil fuel consumption.

Pilot actions for Adrigreen ports

Strengths, Weaknesses, Opportunities, and Threats analysis of Adrigreen ports

P1, P2, and P3 are listed among the trans-European transport network (TENT-T) maritime ports. Ancona is recognised as core port within the Scandinavian-Mediterranean Corridor, while Pula and Dubrovnik are comprehensive ports.

As a general remark, Pula port has its strategic asset in leisure maritime activities, while Dubrovnik port is a very important port for cruises calling the Adriatic Sea. Also, it has local ferries connecting the port to the main Croatian island.

Ferries connecting the Doric shores to Croatia, Albania, and Greece, are the strategic asset of the port of Ancona, both in terms of passengers and freight flows. Furthermore, the port of Ancona is a multipurpose port, thanks to the presence of different maritime activities having an increasing role in the development of Marche Region economy, generating nearly 2.7% of regional GDP.

A common Strength of P1 and P3 is their geographical location. A system has been implemented by P2 port for quality management and environmental management protection based on standards.

A common Strength of P1, P2, and P3 is the proximity of their port to the city centre. This represents also a common Weakness, because the port activities can affect the quality of life of the people living nearby the port area. The environmental footprint of ports includes emission of airborne pollutants and greenhouse gases, noise, water and soil pollution.

For example, port shipping and ground movements were reported to contribute to the yearly average ambient levels of PM_{10} (19%), NO_2 (25%) and SO_2 (43%) of the nearby city by the Tyrrhenian Sea (Gobbi et al. 2020). Long term exposure to airborne pollutants has been recognized as a factor causing adverse health effects (WHO 2013). Long term effects on mortality were reported by Bauleo et al. (2019) for the residents in the proximity (<500 m) of an Italian port, with higher risk of mortality from lung cancer and all cancers.

A common Weakness is represented by the lack of regular data collection and environmental monitoring.

Both P3 and P2 ports have structural barriers for the production and use of renewable energy sources.

The availability of EU financial instruments is a common Opportunity of the three ports. Moreover, the three ports are active in international projects aimed at building new infrastructures, improving accessibility, operations management, and environmental protection.

A common Threat of the three ports may be the need for large investments for new infrastructures.

A Threat reported by P1 port is the Lack of a dedicated road infrastructure with the consequence of road congestion during disembarking.

Threats for P2 port are the environmental externalities deriving from an increase in ship calls and lack of communication and coordination between institutions and other stakeholders involved in environmental protection.

P3 port considers a Threat collecting and analysing data for the application of green and sustainable technologies.

‘P1’ port – SWOT analysis

Strengths	Weaknesses
- The port, embedded in the Ports Authority system, has a strategical geographic position for the ferry traffic: nearly 19% on the international ferry passenger traffic of the national ports embark and/or disembark in the port, as it has a competitive transit time to Balkan countries and Greece; - The port has daily departures for Greece and it is the main national port on the Italy-Croatia ferry traffic. It has also a regular line to Durres; - Concerning the TEN-T European transport policy, the port is recognised as core port within the SCAN-MED corridor, a crucial north-south axis for the European economy.	- The port is very close to the city centre, as it is an historical port, embedded in the urban context; - Therefore, the port promoted the signature of the “Blue Agreement”, with the aim to reduce the sulphur content of maritime fuel for the companies willing to commit to it, contributing to the environmental sustainability of the port; - In addition, to face to the increasing need of additional areas to be dedicated to port activities, the Ports Authority is rationalising and upgrading the existing infrastructures, adapting it to the new needs.
Opportunities	**Threats**
- Thanks to recent road infrastructure improvements, the port is a gateway to reach Eastern Balkans also for passengers coming from inland area, increasing its catchment area; - Furthermore, territories surrounding the port are very attractive from a tourist point of view, making the port very competitive for cruise companies. Thus, the Ports Authority is going to realise a new quay and cruise terminal, to strengthen the role of the port in the cruise market; - In addition, the port is a multipurpose port, where different maritime sectors contribute to its competitiveness on the international stage (passengers and freight traffic, high quality mechanical engineering, fishing sector, logistics, and tourism).	- The port lacks a dedicated road infrastructure to connect it to highways. This is a quite sensitive issue, as the port is a leader in ferry transport. So far, tracks and trailers pass through a densely populated area to join highway, creating also congestions in urban roads, especially during disembarking; - However, the technical - economic feasibility project for the construction of a dedicated link between the Port and the national main roads has been approved; - This will ensure a smooth connection between land and sea infrastructures, essential to guarantee the future competitiveness of the port.

'P2' port – SWOT analysis

Strengths	Weaknesses
- Available programmes and technological documents for environmental management of port according to the national, European and International environmental legislation; - Basic administrative structures created at the local level for implementation and enforcement of environmental legislation; - Change in structure of passenger transport turnover in port (e.g., increase of homeport and Ro-Ro traffic leading to decrease of the unhealthy impact of cruise transit ships on environment in port area); - Initiatives of port authority taken to protect the environment (e.g., implementation of a project regarding environmental monitoring); - Communication policy and practice for informing the society about initiatives taken to protect the environment; - There is the certified plan by the International Code for Security of Ships and Port Facilities (ISPS Code), establishing a system for quality management and environmental management protection based on standard ISO 9001/2015 and ISO 14001/2015.	- Lack of facilities for the use of renewable energy sources; - Lack of facilities for onshore power supply (cold ironing); - Lack on energy efficiency of handling equipment (e.g., electrification, energy recovery); - Low sulphur fuel availability; - Lack of self-monitoring system for particular components of the environment; - Limited internal financial resources to ensure environmentally sound operation of the port.
Opportunities	**Threats**
- No nearby industry to the port; - Establishment of the administrative structure for the implementation and enforcement of environmental legislation; - Availability of EU financial instruments in order to ensure a support to operations management processes aimed at environmental protection in the port area; - Increased demands for protection of the environment in the area around the ports in order to develop priority sectors for the country; - Availability of EU financial instruments for support of EU port; - Operations management and environmental protection (e.g., participation in international projects).	- Low environmental consciousness; - Resisting bad practices; - Slow implementation of new legislation; - Lack of communication and coordination between institutions and other stakeholders responsible for implementing environmental legislation; - Expected increase in ship call in the ports, which is a potential danger to environmental protection.

‘P3’ port – SWOT analysis

Strengths	Weaknesses
- Advantageous geographical location.	- Monitoring of the port and collection of data is bad and incomplete; - Environmental laws poorly implemented; - Infrastructure does not support the transition to sustainable energy sources; - No renewable energy resources are used; - Poor waste-water management.
Opportunities	**Threats**
- Use of European Union funds; - Investment in new infrastructure (e.g., wastewater treatment plant); - Improving accessibility; - Investment in new green maintenance equipment; - Learning from other ports how to reduce waste; - Learning from others with the aim of raising the quality of service and maintenance.	- Large investments; - Legislation that poorly supports self-sustainable development; - Collecting and analysing data for the application of new technologies that enable the use of renewable energy sources and the sustainable development of the port.

Energy management

Energy efficiency (previously referred to as energy consumption) ranked third in the list of environmental priorities of the port sector in 2020 as reported by ESPO (2020).

Ports and terminals, with associated transport networks and equipment heavy operations, are major energy consumers and greenhouse gases emitters. Thus, challenging climate change continues to be one of the top priorities for ports and it is closely interlinked with energy consumption. Generally, the highest fraction of the carbon footprint deriving from energy consumption is related to electricity. In this framework, also due to the lack of information reported by Adrigreen Ports and the exit from the project of Low Adriatic Port Authority, only electricity consumption has been taken into account for the project. In 2018, the consumption of electricity for all ports varied in the range 692–2500MWh.

To show the importance of electricity consumption in terms of carbon footprint, global greenhouse gases emissions are reduced by 205g and 344g CO2eq in Croatia and Italy, respectively, for each kWh saved (Koffi et al. 2017). Consequently, implementing initiatives that reduce the electricity consumption at ports not only means budget savings but also brings benefits to the global environment.

Figure 19 shows differences in greenhouse gases emissions deriving from ports' yearly mean electricity consumption compared to the overall mean electricity consumption of the Adrigreen ports. Mean electricity consumption about 7.5kWh/passenger above the overall mean leads to about 83.3t of extra CO2eq emissions each year, whereas electricity consumption between 3.2–4.3kWh/passenger below the overall mean corresponds to 1174.3–1155.2t of lower CO2eq emissions each year.

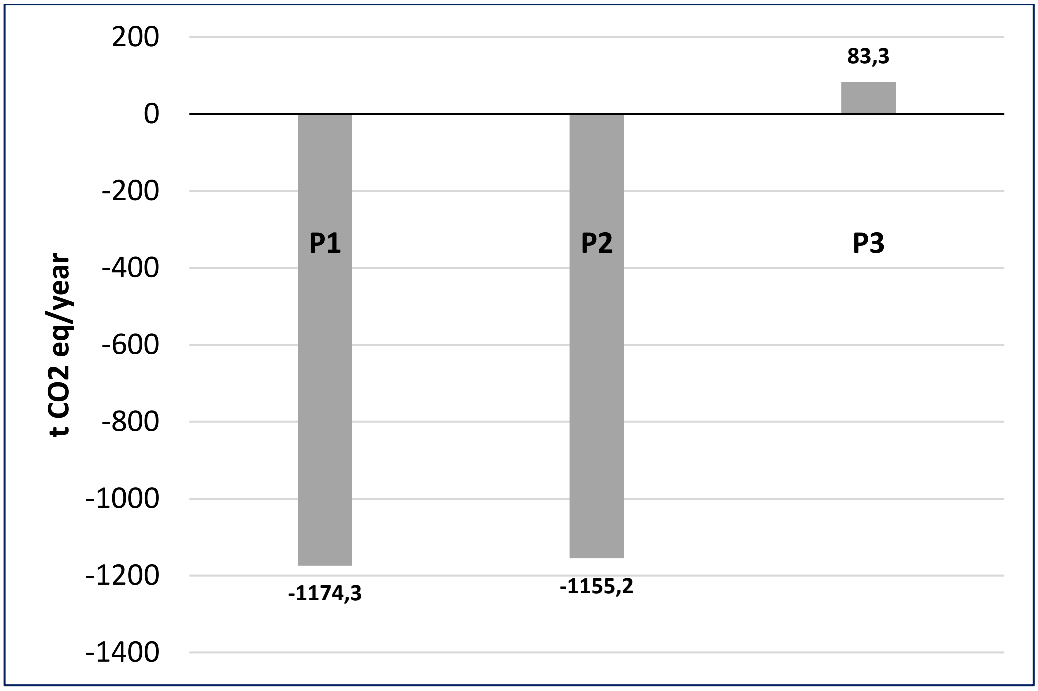


Figure 19 Disparities in greenhouse gases emissions related to the difference between ports' yearly mean and overall mean electricity consumption in the time period 2016 – 2018.

The initiatives that can be implemented (Table 15) can be divided into short-term initiatives and long-term initiatives. For example, a short-term initiative is to switch to fully LED lighting technology. Ideal for indoor/outdoor areas of terminals and buildings, in most cases this technology is being coupled with intelligent control systems, featuring different functions and capabilities (e.g., remote-controlling, automation, etc.). On the other hand, a geothermal-energy plant for heating and cooling can be considered a long-term initiative.

Such actions aimed at reducing electricity consumption would have an impact on the total energy consumption of the ports and on the related bills but would also result in decreasing the carbon footprint of the port activities. In contrast, the actions aimed at decarbonizing electricity consumption would impact the carbon footprint of the port activities but would, almost certainly, increase the electricity bills.

Figure 20, Figure 21, and Figure 22 show a comparison between ports' yearly mean and overall mean electricity consumption in terms of budget. Considering the P3 mean cost of about 0.063€/kWh, P3 yearly mean electricity consumption about 7.5 kWh/passenger above the overall mean corresponds to spending up to extra 25,401€. Considering P1 and P2 mean coast of about 0.091€/kWh and 0.039€/kWh respectively, P1 and P2 yearly mean electricity consumption between 3.2 and 4.3kWh/passenger below the overall mean leads to savings between 219,003€ and 312,007€ each year. P1 provided an average price related to electricity consumption. Therefore, a fixed value was considered for the time period 2016–2018.

General action	Specific Short-Term Long-Term Action	Metrics	Applicable to	Status	Strengths Weaknesses (Index)	Opportunities Threats (Index)
Decreasing electricity consumption	Light-emitting diodes (LED) lightning (STA).	Electricity consumption (kWh); GHG emissions (CO2eq)	P1	1	1	0
			P2	3	N/A	N/A
			P3	1	2	1
Decreasing electricity consumption	Energy monitoring system (STA).	Electricity consumption (kWh); GHG emissions (CO2eq)	P1	2	1	1
			P2	2	2	2
			P3	2	2	1
Decarbonizing electricity consumption	Photovoltaic or solar panel (STA).	Electricity consumption (kWh); GHG emissions (CO2eq)	P1	1	1	1
			P2	1	2	2
			P3	1	2	1
Decreasing electricity consumption	Passive house concept and eco-building standards (LTA).	Electricity consumption (kWh); GHG emissions (CO2eq)	P1	1	2	0
			P2	1	2	0
			P3	1	2	0
Decarbonizing electricity consumption	Geothermal energy plant for heating and cooling (LTA).	Electricity consumption (kWh) from commercial grid; GHG emissions (CO2eq)	P1	1	2	1
			P2	2	2	2
			P3	1	2	0
Decarbonizing electricity consumption	Purchase of electricity generated from a mix of renewable energy sources (STA).	GHG emissions (CO2eq); Amount of renewable energy purchased by the port, as a percentage of total energy consumed	P1	1	1	0
			P2	1	1	1
			P3	1	1	0
Decarbonizing electricity consumption	Wave energy converters (LTA).	Electricity consumption (kWh) from commercial grid; GHG emissions (CO2eq)	P1	1	1	1
			P2	1	2	2
			P3	1	2	0
GHG = Greenhouse Gases; N/A = Not Applicable; LTA = Long Term Action; STA = Short Term Action						

Table 15 Actions related to electricity consumption and potential indicators.

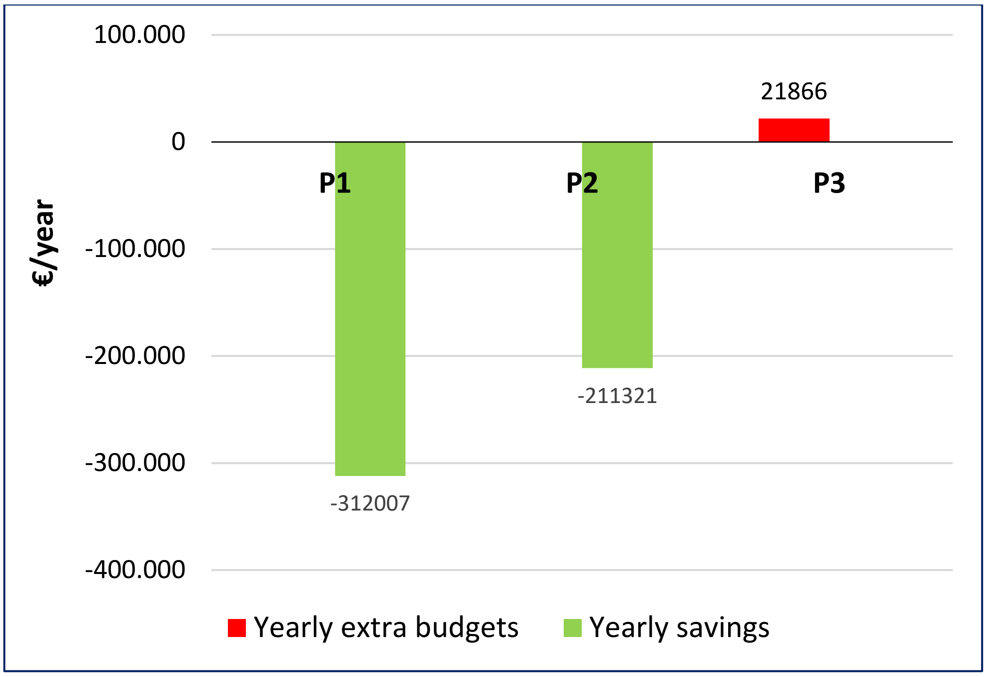


Figure 20 Yearly savings/extra budgets deriving from electricity consumption below/above the Adrigreen ports' consumption benchmark based on Adrigreen ports' specific minimum cost in the time period 2016–2018: P1=0.091€/kWh, P2=0.038€/kWh, P3=0.054€/kWh.

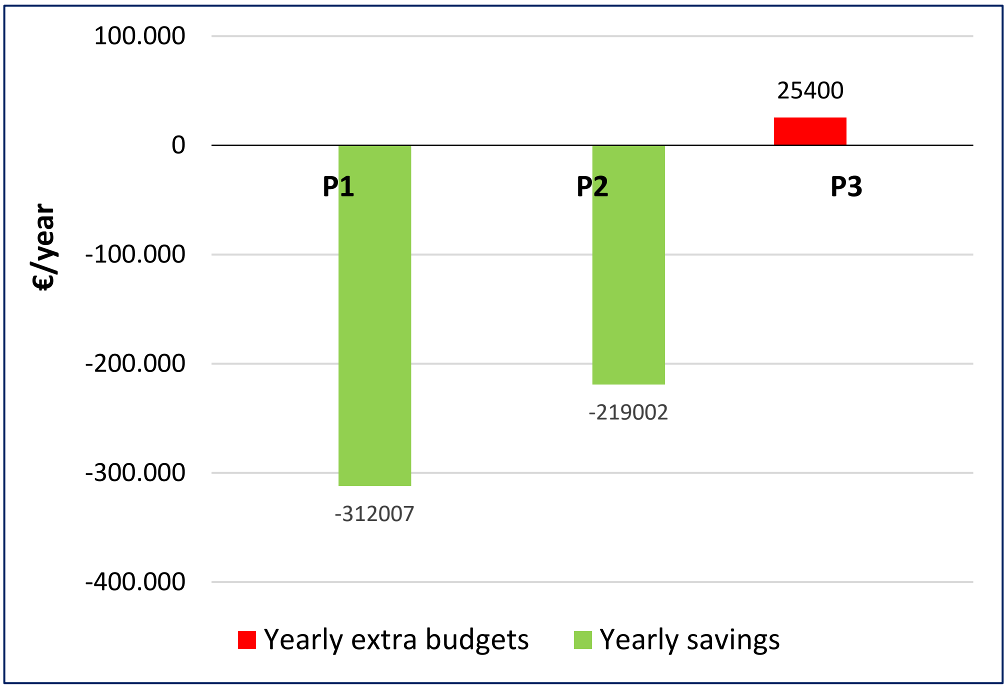


Figure 21 Yearly savings/extra budgets deriving from electricity consumption below/above the Adrigreen ports' consumption benchmark based on Adrigreen ports' specific average cost in the time period 2016–2018: P1=0.091€/kWh, P2=0.039€/kWh, P3=0.063€/kWh.

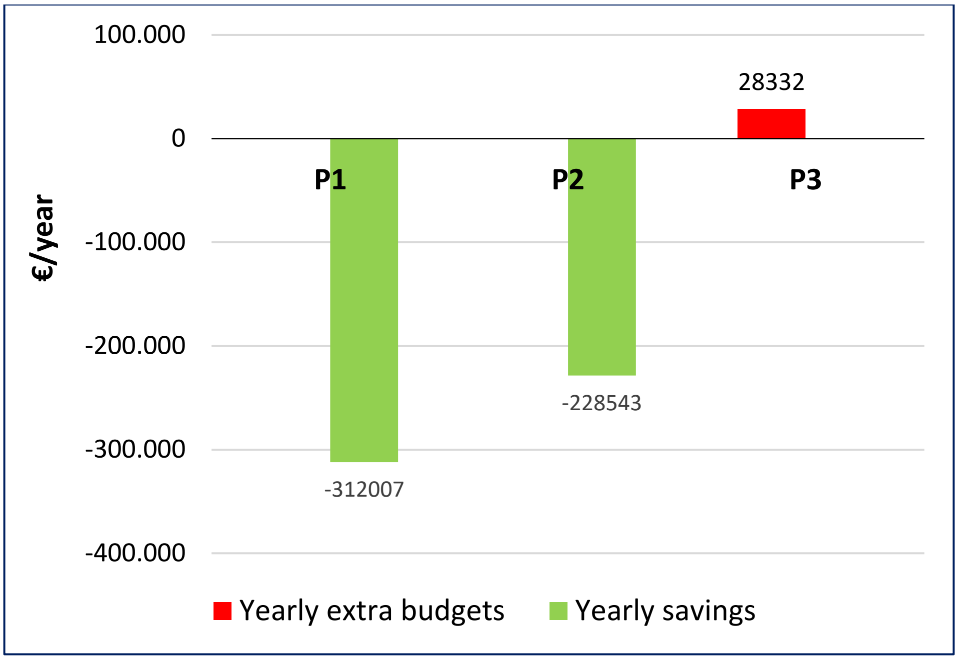


Figure 22 Yearly savings/extra budgets deriving from electricity consumption below/above the Adrigreen ports' consumption benchmark based on Adrigreen ports' specific maximum cost in the time period 2016–2018: P1=0.091€/kWh, P2=0.041€/kWh, P3=0.070€/kWh.

Table 16 summarizes relevant/reference case studies regarding actions aimed at decreasing the carbon footprint of electricity consumption at the ports.

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 (CO2eq); 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 (CO2eq)	Port of Ostend.
GHG = Greenhouse Gases			

Table 16 Port reference case studies for actions aimed at decreasing the carbon footprint of electricity consumption.

Water management

Water quality issues ranked 7th in the list of environmental priorities of the port sector as reported in 2020 by ESPO (2020).

The contamination of fresh water may occur during the unloading/loading of ships' tanks, port activities, and leakages. Water contamination may be exacerbated by the absence of water quality monitoring system. As a general rule, reducing water consumption reduces the chances of water contamination and leakages by avoiding unnecessary water depletion.

In 2018, water consumption at Adrigreen ports varied in the range 2,313–124,916m3.

Considering the significant gap between these figures, it is important to remind that, apparently, only P1 provides water to all types of ships calling at the port.

The reduction in water consumption would also result in decreasing greenhouse gases emissions deriving from water management. For example, in Italy the use of one m3 of drinking water corresponds to the emission of 0.579kg CO2eq (Dominici Loprieno et al. 2017).

Figure 23 shows the differences in greenhouse gases emissions deriving from ports' yearly mean water consumption compared to the overall mean water consumption of the Adrigreen ports. Mean water consumption about 63.9l/passenger above the overall mean leads to 40t of extra CO2eq emissions each year, whereas mean water consumption between 17.1 and 46.8l/passenger below the overall mean corresponds to 0.5–35.5t less CO2eq emissions each year.

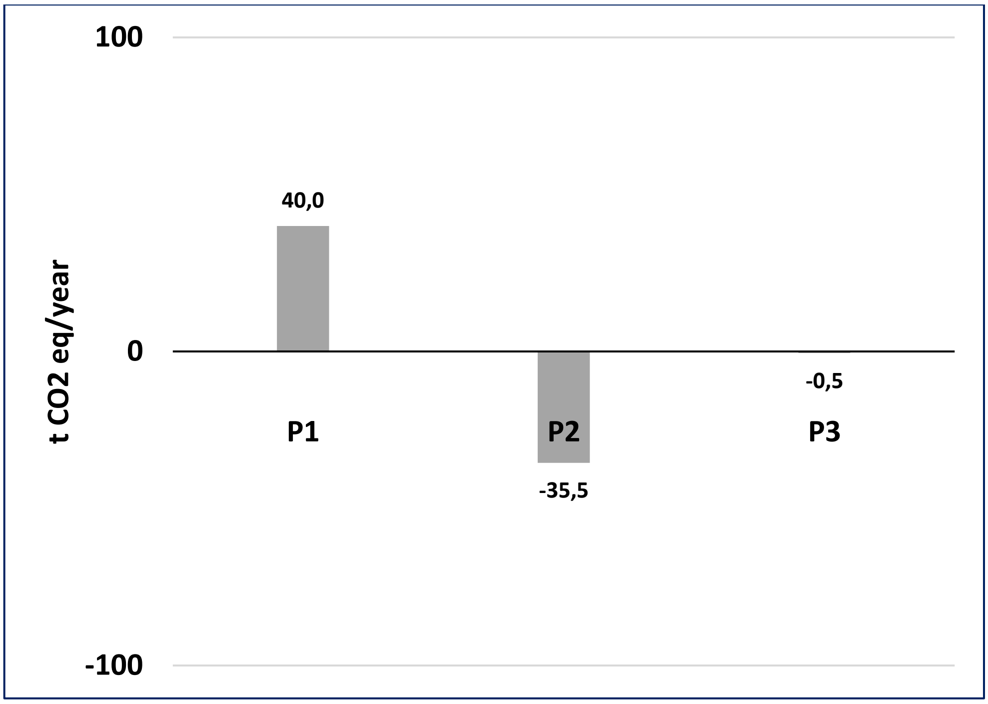


Figure 23 Disparities in greenhouse gases emissions deriving from the difference between ports' yearly mean and overall mean water consumption in the time period 2016 – 2018.

The initiatives that can be implemented (Table 17) were divided into short-term initiatives and long-term initiatives. For example, a short-term initiative is to reduce water consumption from public and offices toilettes introducing dual-flush toilettes or variable flush toilettes, reducing toilettes cistern capacity, or installing flow regulator for hand washing (time sensor, aerator etc.). Instead, a new wastewater treatment plant with re-use is a long-term initiative. This is a solution that helps cities that are near to or next to ports simply by removing the port from the main water/wastewater networks of the city.

As already outlined, actions aimed at reducing water consumption would have an impact on the total water consumption and the related bills and would also result in decreasing the carbon footprint of the port activities.

General action	Specific Short-Term Long-Term Action	Metrics	Applicable to	Status	Strengths Weaknesses (Index)	Opportunities Threats (Index)
Decreasing water consumption	Monitoring of water consumption (STA)	Water consumption (m3, l/passenger)	P1	2	1	1
			P2	2	2	2
			P3	1	2	2
Decreasing water consumption	Rainwater collection and reuse (LTA)	Water consumption (m3, l/passenger)	P1	1	1	1
			P2	3	N/A	N/A
			P3	1	2	2
Reducing water footprint	Organize training and education of port staff (STA)	Participants' satisfaction	P1	2	0	0
			P2	1	0	1
			P3	1	1	1
Reducing water pollution	Surface water and groundwater quality monitoring (STA)	Water quality criteria	P1	3	N/A	N/A
			P2	3	N/A	N/A
			P3	1	2	2
Decreasing water consumption	Public/office toilettes devices (STA)	Water consumption (m3, l/passenger)	P1	1	1	0
			P2	1	1	0
			P3	1	1	0
Decreasing water consumption	Ships reward system to reduce consumption (STA)	Water consumption (m3, l/passenger)	P1	1	2	1
			P2	1	2	2
			P3	1	2	2
Improving water quality	Wastewater treatment plant (LTA)	GHG emissions (CO2eq)	P1	1	-1	-1
			P2	1	-1	0
			P3	0	N/A	N/A
GHG = Greenhouse Gases; N/A = Not Applicable; LTA = Long Term Action; STA = Short Term Action						

Table 17 Actions to reduce the water footprint and consumption of the port infrastructures and related indicators.

Figure 24, Figure 25, and Figure 26 show a comparison between ports' yearly mean and overall mean water consumption in terms of budget. The port P1 provided an average price related to water consumption. Therefore, such fixed value was considered for the time period 2016–2018. Considering the mean price of water consumption of about 3.45€/m3 for P1 port, P1 yearly mean water consumption about 63.9l/passenger above the overall mean leads extra costs up to 238,197€ per year. Considering the mean price of water consumption for P3 and P2 4.05€/m3 and 7.85€/m3 respectively, P3 and P2 yearly mean water consumption between 17.1–46.8l/passenger below the overall mean corresponds to saving between 3,764€ and 480,225€ each year.

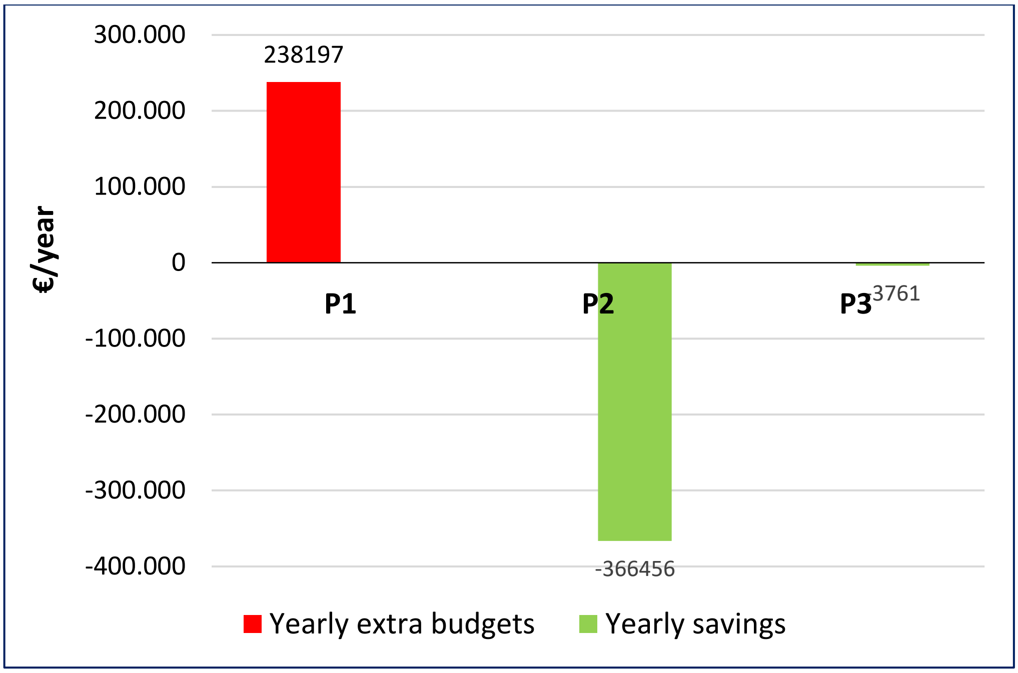


Figure 24 Yearly savings/extra budgets deriving from water consumption below/above the Adrigreen ports' consumption benchmark based on Adrigreen ports' specific minimum cost in the time period 2016–2018: P1=3.45€/m3, P2=6.0€/m3, P3=4.0€/m3.

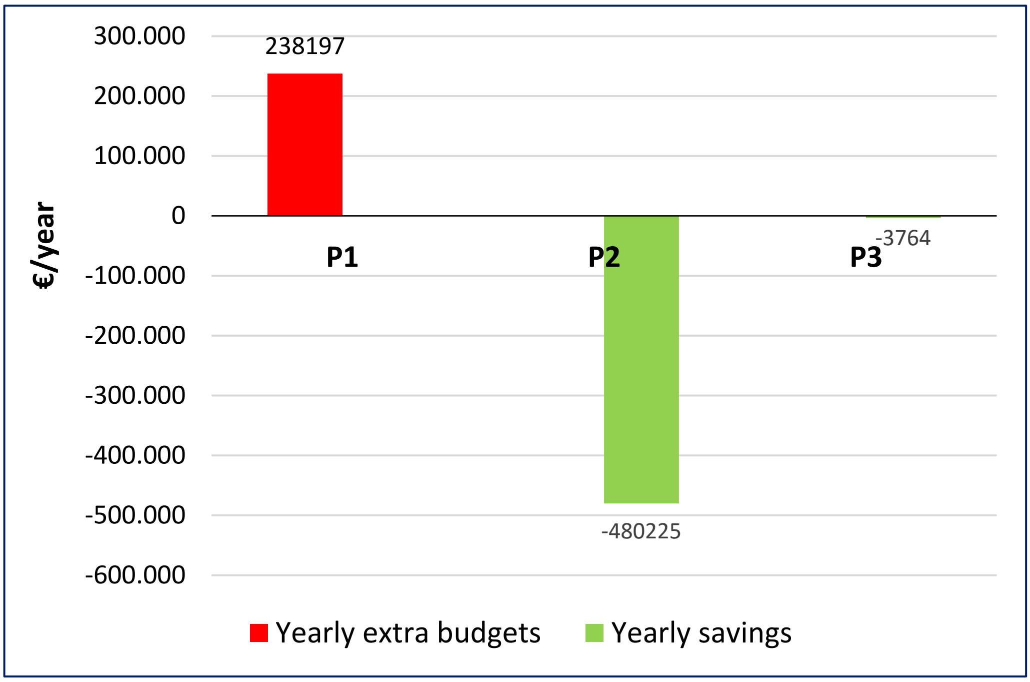


Figure 25 Yearly savings/extra budgets deriving from water consumption below/above the Adrigreen ports' consumption benchmark based on Adrigreen ports' specific average cost in the time period 2016–2018: P1=3.45€/m3, P2=7.85€/m3, P3=4.05€/m3.

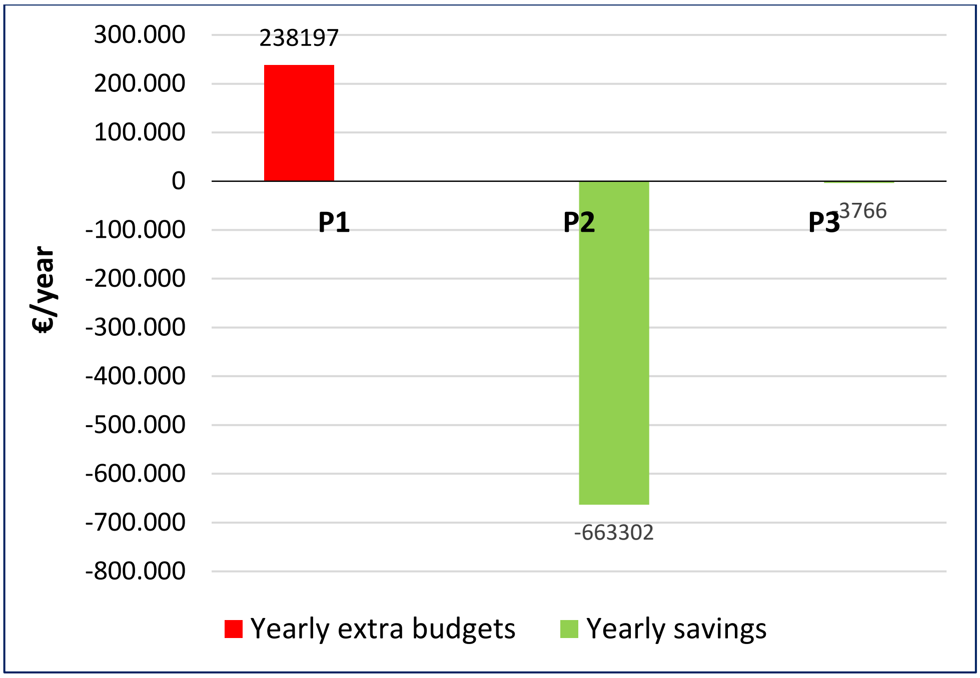


Figure 26 Yearly savings/extra budgets deriving from water consumption below/above the Adrigreen ports' consumption benchmark based on Adrigreen ports' specific maximum cost in the time period 2016–2018: P1=3.45€/m3, P2=10.8€/m3, P3=4.1€/m3.

Table 18 summarizes relevant/reference case studies for actions aimed at decreasing the footprint of water consumption at Adrigreen ports.

General action	Specific action	Metrics	Port reference case studies
Decreasing water consumption	Monitoring of water consumption	Water consumption (m3, l/passenger)	Port of Venice.
Decreasing water consumption	Rainwater reuse	Water consumption (m3, l/passenger)	P2 port (this study).
Reducing water footprint	Organize training and education of port staff.	Participants' satisfaction	Port of Venice; Website port of Rotterdam.
Reducing water pollution	Surface water and groundwater quality monitoring	Water quality criteria	P1 port (this study); P2 port (this study).
Decreasing water consumption	Public/office toilettes devices	Water consumption (m3, l/passenger)	It is a very common practice.
Decreasing water consumption	Ships reward system to reduce consumption	Water consumption (m3, l/passenger)	Website port of Rotterdam.
Improving water quality	Wastewater treatment plant	GHG emissions (CO2eq)	Port of Nantes-Saint Nazaire.
GHG = Greenhouse Gases			

Table 18 Reference case studies for actions aimed at decreasing the footprint of water consumption at Adrigreen Ports.

Waste management

Ship waste and port waste ranked 6th and 8th, respectively, in the list of environmental priorities of the port sector in 2020 as reported by ESPO (2020). In addition, about two thirds of European ports are today certified through an environmental standard (e.g., ISO14000, EMAS, EcoPorts' PERS), which is an increase by 11% since 2013. Today, 81% of the ports have set up an environmental monitoring program, with waste being the most monitored issue (ESPO 2020).

One of the main problems of the ports is to organize the collection of waste from ships and the quay activities. Due to the complexity of such activities, port authorities very often rely on one or more external companies.

In all the ports involved, waste management is de-centralized, and it is implemented through external companies. P1 has appointed a private company for the collection and the recycling of waste unloaded from ships and due to quay activities while the municipal waste company collects and recycle general waste from the remaining port area. This made rather difficult the benchmarking of this processes.

P2 port and P3 port have implemented plans regarding arrangements to introduce reuse or recycling of waste unloaded from the ships. Specifically, the local municipal waste company is in charge of the reuse or recycling of waste from the ships at P2 port.

Diverting waste away from landfills has also an impact on climate change in terms of reduction in greenhouse gases emissions. For example, each kilogram of general waste stockpiled in landfills leads to the emission of up to one kilogram of CO_2eq (Oficina Catalana del Canvi Climàtic 2019).

Again, the initiatives that to be implemented (Table 19) can be divided into short-term initiatives and long-term initiatives. For example, a short-term initiative is to monitor waste production. In fact, one of the problems is that by delegating waste management to external companies, the port authorities find difficult to monitor the process and the related data. Another short-term initiative could be to reduce waste-management fees based on the so-called Environmental Ship Index (ESI).

General action	Specific Short-Term Long-Term Action	Metrics	Applicable to	Status	Strengths Weaknesses (Index)	Opportunities Threats (Index)
Promoting waste prevention and recycling	Economic incentives for recycling more and generating less waste (STA)	tons of waste fractions/year	P1	1	1	0
			P2	1	1	0
			P3	1	2	1
Waste pollution prevention	Disposable plastic cutlery and beverages replaced with easily degradable materials (STA)	kg plastic waste/pass	P1	3	N/A	N/A
			P2	1	1	1
			P3	1	2	1
Promoting waste recycling	Training of employees on recycling (STA)	tons of waste fractions/year	P1	2	1	0
			P2	1	1	1
			P3	1	1	0
Promoting waste recycling	Instructions for waste separation at the passenger terminal (STA)	kg/pass	P1	1	1	0
			P2	1	1	1
			P3	1	1	1
Waste pollution prevention	Monitoring of waste production (STA)	Waste produced (tons, tons/pass)	P1	2	1	1
			P2	2	1	1
			P3	2	1	1
Promoting waste reuse	Use of environmentally friendly asphalt for repaving parking lots and runways (LTA)	tons of recycled asphalt; emissions of GHG and airborne pollutants	P1	1	1	1
			P2	1	1	1
			P3	1	1	1
GHG = Greenhouse Gases; N/A = Not Applicable; LTA = Long Term Action; STA = Short Term Action						

Table 19 Actions related to improve waste management of the port infrastructures and related indicators.

Table 20 summarizes relevant/reference case studies for actions aimed at decreasing the footprint of waste management and production at Adrigreen ports.

General action	Specific action	Metrics	Port reference case studies
Promoting waste prevention and recycling	Economic incentives for recycling more and generating less waste	tons of waste fractions/year	Port of Rotterdam.
Waste pollution prevention	Disposable plastic cutlery and beverages replaced with easily degradable materials	kg plastic waste/passenger	P1 port (this study). Website port of Antwerp.
Promoting waste recycling	Training of employees on recycling	tons of waste fractions/year	Website port of Seattle.
Promoting waste recycling	Instructions for waste separation at the passenger terminal	kg/passenger	Common practice at passenger terminals.
Waste pollution prevention	Monitoring of waste production	Waste produced (tons, tons/passenger)	Website port of Genoa.
Promoting waste reuse	Use of environmentally friendly asphalt for repaving parking lots and port area	tons of recycled asphalt; emissions of GHG and airborne pollutants	D'Angelo et al. (2008).
GHG = Greenhouse Gases			

Table 20 Reference case studies for actions aimed at decreasing the footprint of waste production at port infrastructures.

Sustainable transportation of passengers from/to airport/port infrastructures

According to a report about transport development by Republic of Croatia (2017), cars are the most popular means of transportation with about 51% of all trips (40.8% as a driver and 10.4% as a passenger), followed by walking 30% and public transport (bus, tram, train, and ferry) 12%.

Maritime transport is fundamental for the connection of Croatian mainland and islands. The improvement of links between maritime public transport and local public transport represents an opportunity both for domestic and international passengers.

The monthly distribution of passengers in Croatian airports shows a seasonal trend with the highest volume of passengers in July and August and the lowest in February. This seasonal trend is due to the volume of passengers on international flights within the touristic season, whereas the volume of passengers on domestic flights is quite steady throughout the year (Republic of Croatia 2017). Therefore, the initiatives aimed at improving sustainability of transport modes to/from airports may be tailored for the different types of passengers. A very similar situation almost certainly occurs at Italian Adrigreen airports.

Table 21 (adapted from National Transportation Ministry, Republic of Croatia 2017) shows the estimated share of transport modes in the access to Dubrovnik and Pula airports. Railway or tram connections are not available at any Croatian airport.

Airport	Bus	Car	Taxi
Dubrovnik	35%	33%	32%
Pula	28%	40%	32%

Table 21 Estimated modal split in the access to airports according to the transport offer.

In Italy, the demand for local public transport showed a decrease of about 2% between 2014 and 2016 (ISPRA 2018).

Between 2014 and 2016, the city of Rimini confirmed the national trend, with a decrease of about 5% in in the demand for local public transport. In contrast, the demand for local public transport increased in Ancona (about 4%), Bari (about 21%), Brindisi (about 15%), and Pescara (about 1%). Figure 27 (adapted from ISPRA 2018) shows the number of passengers per year vs. number of inhabitants of the municipality for the five Italian cities considered within this study.

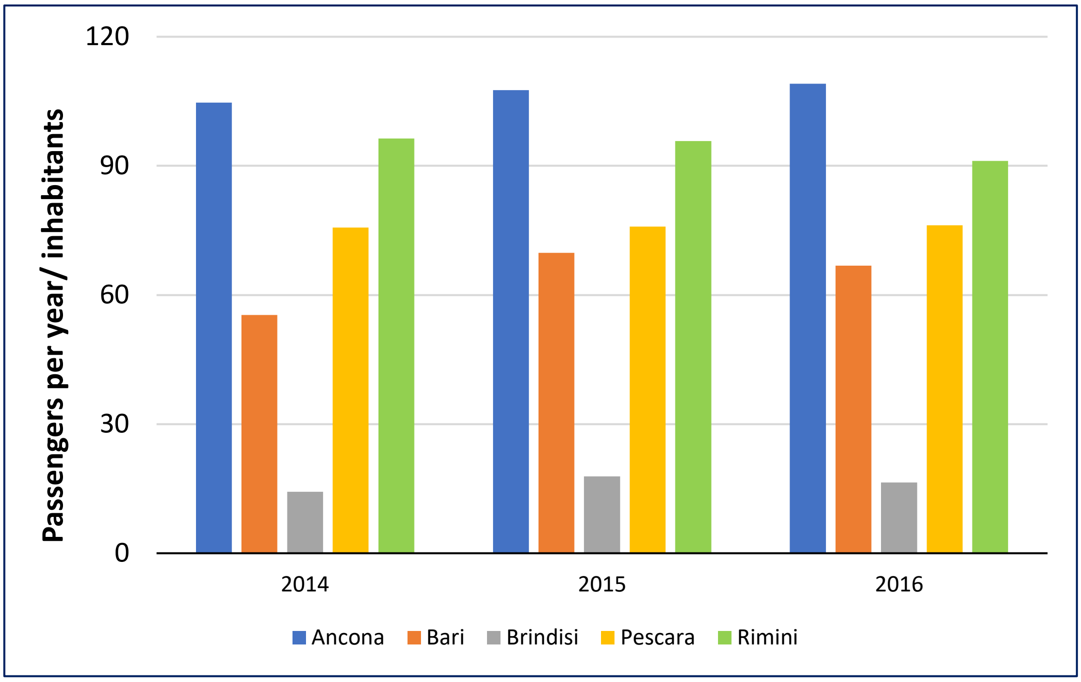


Figure 27 Demand for local public transport in the provincial capital municipalities of Ancona, Bari, Brindisi, Pescara, and Rimini (Italy). The values were estimated for Rimini for the years 2014–2016 and for Pescara for the year 2016.

It is important to notice and take into account that the choice of mobility indicators may affect the comparison between public transportation systems of different cities. For example, Table 22 (adapted from Pinna et al. 2017) shows different rankings of three Italian cities that arise from considering two different indicators.

Indicator [unit]	Note	Ranking
Bus network density [km/km2]	Extension of the network vs. area under the jurisdiction of the municipality	Bari> Rimini> Ancona
Demand for public transport [passenger/y/inhabitants]	Number of passengers per year vs. number of inhabitants of the municipality	Ancona> Rimini> Bari

Table 22 Ranking of public transport indicators for the cities of Ancona, Bari, and Rimini in 2015.

Between all the solutions to boost and ease public transportation and intermodality, infomobility systems are information and communication technology systems such as variable message panels that display real-time traffic information at public transport stops, indication of routes and waiting times, websites serving public transport users and travel planning applications, electronic ticketing systems and/or online sales of public transport tickets, etc. Infomobility systems represent an option to let passengers easily plan and experience their travel. In 2013, infomobility systems were operating at Ancona, Bari, and Pescara (ISTAT 2014).

According to a survey edited by ACI (2018), almost all the airports (namely 98%) are served by public transportation systems. However, the majority of airports' employees and travelers do not use public transport to reach the workplace (ACI 2018). The emissions related to surface access to the airport infrastructure are on-site emissions deriving from non-airport-operator owned sources (ACI 2018). For ports, the emissions deriving from the modes of transportation utilized by the employees are "other indirect sources" under Scope 3 (Azarkamand et al. 2020).

The development of improved public transportation systems aims at discouraging the use of private cars providing travelers with fast, environmental-friendly and cost-effective transport solutions. This requires a joint effort of port/airport management and local stakeholders as well as a more positive attitude towards public transport.

Table 23 (adapted from a work by Reichmuth 2010) shows public and private ground access modes to airports or ports. Other actions aimed at improving the sustainability of transportation in the airport infrastructures were recently reported in a work by Greer et al. (2020).

Transport means	Description	Pros and Cons
Car	Own car parked at port/airport	Parking fees represent an important revenue especially for airport operators.
	Kiss-and-ride	No parking fees; Generates pollution and GHG.
	Rental car	Revenue for airport operators deriving from the rent of offices and parking spaces.
	Taxi	Maximum flexibility; Generates pollution and GHG.
Rail	Both short and long distances	No traffic jam, high capacity; Rail service may increase the catchment area of the airport/port; Waiting time may be reduced for the travelers; Parking revenue may decrease.
Coaches	Long distance coaches	Long distance coaches in regions with less well developed rail network or none; Possibility of intermodal competition.
Bus	Public transport busses for short distances	Regular bus service; Travelers may associate bus service to traffic jam; Crowded place not suitable for carrying a luggage; Buses dedicated to airports/ports (express buses) with space for luggage; Higher fares for express buses.
GHG = Greenhouse Gases		

Table 23 Transport modes to access airports and ports.

Table 24 reports examples of pilot actions aimed at promoting sustainable mobility at ports/airports and the related SWOT analysis.

Table 25 summarizes relevant/reference case studies for actions aimed at promoting sustainable mobility from/to airport and port infrastructures.

Further, more-in-deep, analyses and proposals regarding multimodality at Adrigreen ports and airports will be presented in an addendum to the present report. In fact, we are now carrying out more studies concerning the short-term and long-term effects of Covid19 pandemic on public transport and multimodality.

Given that the partners already experienced new scenarios deriving from Covid pandemic crisis and the amount of literature describing new scenarios, we expect to perform the following actions before the end of the project.

- Further analysis of relevant literature regarding expected effects of Covid pandemic upon multimodal transportation in Adrigreen framework.
- Collection of new datasheets specialized to assess Covid Pandemic effects upon Adrigreen Partners
- Evaluation of environmental framework of new scenarios for Adrigreen partners and analysis of scenarios with Partners.
- Preparation of ad-hoc technical document to address possible new scenarios for Adrigreen Partners and other comparable players in the Adriatic area.

General action	Specific Short-Term Long-Term Action	Metrics	Applicable to	Status	Strengths Weaknesses (Index)	Opportunities Threats (Index)
Initiatives to foster sustainable mobility	Hotel and car rental shuttle bus consolidation to reduce the number of empty trips (STA)	GHG and airborne pollutants emissions	A1	1	2	2
			A2	1	2	2
			A3	1	1	0
			A4	1	N/A	N/A
			A5	1	2	2
			A6	1	2	0
			P1	1	1	1
			P2	1	1	1
			P3	1	1	1
Initiatives to foster sustainable mobility	Infomobility (LTA)	Customer satisfaction; Demand for public transport	A1	1	2	1
			A2	1	2	-1
			A3	1	1	0
			A4	1	N/A	N/A
			A5	1	2	0
			A6	1	2	2
			P1	1	2	2
			P2	1	2	2
			P3	1	1	1
Initiatives to foster sustainable mobility	Airport/port with an intermodal transport hub (LTA)	Customer satisfaction; Demand for public transport	A1	1	1	0
			A2	1	0	-1
			A3	1	2	1
			A4	0	N/A	N/A
			A5	2	1	1
			A6	1	1	1
			P1	1	1	1
			P2	1	1	1
			P3	0	1	1
Initiatives to foster sustainable mobility	Electric buses (LTA)	Electricity consumption (kW); GHG and airborne pollutants emissions	A1	1	1	0
			A2	1	0	-1
			A3	1	2	1
			A4	1	N/A	N/A
			A5	1	0	1
			A6	1	1	-1
			P1	1	2	1
			P2	1	2	1
			P3	1	1	1
Initiatives to foster sustainable mobility	Airport/Port-rail intermodality train to plain/ship (LTA)	Customer satisfaction; Demand for public transport	A1	0	N/I	N/I
			A2	1	2	0
			A3	0	N/I	N/I
			A4	0	N/A	N/A
			A5	1	2	1
			A6	0	N/I	N/I
			P1	1	2	2
			P2	0	N/I	N/I
			P3	1	2	1
N/A = Not Applicable; N/I = Not Implementable mostly due to lack of infrastructures; LTA = Long Term Action; STA = Short Term Action; GHG = Greenhouse Gases						

Table 24 Actions aimed at promoting sustainable mobility in airports and ports.

General action	Specific Action	Metrics	Reference case studies
Initiatives to foster sustainable mobility	Hotel and car rental shuttle bus consolidation to reduce the number of empty trips	GHG and airborne pollutants emissions	Nanjing Lukou International Airport (Bao et al. 2018).
Initiatives to foster sustainable mobility	Infomobility	Customer satisfaction, demand for public transport	Athens International Airport (Panou et al. 2007); Municipality of Ancona under the INTERREG project E-CHAIN (web site of INTERREG).
Initiatives to foster sustainable mobility	Airport/port with an intermodal transport hub	Customer satisfaction	Web site of Trieste Airport.
Initiatives to foster sustainable mobility	Electric buses	Electricity consumption (kW); GHG and airborne pollutants emissions	Web site of Schiphol Airport; Web site of Brussels Airport (2019).
Initiatives to foster sustainable mobility	Airport-rail intermodality: from train to plain; Port -rail intermodality: from train to ship	Customer satisfaction	Vienna Schwechat Airport (Website of ÖBB).
GHG = Greenhouse Gases			

Table 25 Airport and port reference case studies for actions aimed at promoting sustainable mobility.

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Annex: Example of environmental analysis

Switching from fossil fuel to electric vehicles: comparisons of airborne pollutants and CO2 emissions

Emissions of airborne pollutants (NOx and PM) and CO2 deriving from from the operation of diesel vehicles

For diesel vehicles, the emissions of Nitrogen Oxides NOx, Particulate Matter PM, and Carbon Dioxide CO2 were evaluated following Tier 1, according to Ntziachristos et al. (2019), as follows:

$$E_i = \sum_j EF_{ij} \times FC_j \times U_l$$

where E_i is the emission value of NOx [g], PM [g], or CO2 [kg]; EF_{ij} is the emission factor specific for the type of fuel and the vehicle category (Table 26), [g/kg fuel] for PM and NOx; [kg CO2/kg fuel] for CO2; FC_j is the fuel consumption related to the j-category of vehicle (Table 27) [g/km]; U_l is the usage per year for the l-vehicle (Table 28), [km/year]. All such tables are adapted from Ntziachristos et al. (2019).

Category	**Fuel**	**Airborne pollutants including CO2**	**Unit of emisison factor**	**Emission factor**
Passenger cars	Diesel	NOx	[g/kg fuel]	12.96
Passenger cars	Diesel	PM	[g/kg fuel]	1.10
Passenger cars	Diesel	CO2	[kg/kg fuel]	3.169
Light commercial vehicles	Diesel	NOx	g/kg fuel	14.91
Light commercial vehicles	Diesel	PM	g/kg fuel	1.52
Light commercial vehicles	Diesel	CO2	kg CO2/kg fuel	3.169

Table 26 Tier 1 emission factors for diesel passenger cars and light commercial vehicles.

Vehicle category	Typical fuel consumption [g/km]
Light commercial vehicles	80
Passenger cars	60

Table 27 Tier 1 typical fuel consumption per km, by category of vehicle.

	Vehicle category	Usage [km/year]
Diesel	Light commercial vehicles	*For example: 30,000*
Diesel	Passenger cars	*For example: 15,000*

Table 28 Mileage per year of the vehicles that are going to be replaced during port/airport operations.

More in general, the environmental footprint of each vehicle or any other device operating by an internal combustion engine, can be evaluated introducing two or three parameters along the lines of the above analysis. When dealing with two parameters only, one of them is the so-called “activity indicator” (e.g., km/year, usage hours/year, kg of fuel/year) while the other one is the related emission factor (e.g., g of CO2 per km, g of CO2 per hour, g of CO2 per kg of fuel). When using three parameters, the third one usually links the activity indicator to a more generic emission factor. For example, the generic emission factor g of CO2 per kg of fuel can used either if we know the actual fuel consumption or by assessing its amount by means of a third parameter such as fuel consumption per km or fuel consumption per hour of operation.

Emissions of CO2 deriving from the operation of electric vehicles

Local emissions of airborne pollutants is assumed to be null for the electric vehicles. This is not true, as already outlined, for Particulate Matter since an electric car still emits them due to wear of mechanical parts, brakes and tires. At the moment such emissions have not been adequately measured for electric vehicles so it is impossible to calculate them. On the other hand, emissions of airborne pollutants and CO2, due to the production of electricity and the related technology, should be taken into account.

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

$$E_i = \sum_j FC_{ij} \times EF_j \times T_i$$

where FC_j is electricity consumption related to the battery capacity of electric vehicles [kWh]; EF_{ij} is the emission factor of 397 g CO2eq/kWh that was determined for Italy in 2017 (Gestore Servizi Elettrici 2018); T_i is the number of battery charges per year for the *i*-vehicle, [-].

For the i-vehicle, the number of battery charges per year (T_i) is obtained as follows:

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

Where U_i is the usage per year for the *i*-vehicle (Table 29), [km/year]; R_i is the range of the *i*-type of battery reported by the manufacturer, [km].

Type of vehicle	Model	Manufacturer	Engine power [kW]	Range* [km]	Battery capacity* [Wh]	Utilization each unit [km/year]
Electric scooter	*e.g. Model1*	*e.g. Manufacturer1*	*e.g.* 0.3	*e.g.* 45	*e.g.* 473.6	*e.g.* 2,000
Electric bicyle	*e.g. Model2*	*e.g. Manufacturer2*	*e.g.* 0.25	*e.g.* 70	*e.g.* 360	*e.g.* 3,000
Electric pick-up vehicle	*e.g. Model3*	*e.g. Manufacturer3*	*e.g.* 10	*e.g.* 201	*e.g.* 19200	*e.g.* 10,000
Electric pick-up vehicle	*e.g. Model4*	*e.g. Manufacturer4*	*e.g.* 5	*e.g.* 135	*e.g.* 14400	*e.g.* 15,000

Table 29 Technical specifications and usage per year of the electric vehicles purchased to replace some fossil fuel vehicles.

Also for electric vehicles or devices the assessment can be performed either using two parameters or three ones. In this case the activity indicator is still hours/year or km/year or simply kWhe/year, while the generic emission factor is, for example g of CO2 per kWhe. The amount of electricity consumed can be evaluated as above or with any other proper combination of activity indicators and the related consumption parameters.

Case study: variation in emissions of airborne pollutants (NOx and PM) and CO2 deriving from switching from diesel vehicles to electric vehicles

Pilot action: acquisition of electric vehicles to be used in place of diesel vehicles.

The purchase of electric vehicles would be under the pilot action field that concerns the reduction of energy consumption and environmental footprint. CO2 emissions can be considered as a proxy variable both for energy consumption and for other airborne pollutant emissions. This implies that lower CO2 emissions are likely combined with lower energy consumption and lower emissions of airborne pollutants. Of course this assumption is absolutely wrong whenever lower CO2 emissions are due to the self-production or the purchase of "green electricity".

Fuel	Vehicle category	Mileage [km/year]
diesel	Light commercial vehicle	30,000
diesel	Passenger car	15,000
diesel	Passenger car	12,000
diesel	Passenger car	12,000

Table 30 Example of mileage per year of the diesel vehicles that are going to be replaced by an Adrigreen partner.

Veichle	Type of vehicle	Manufacturer	Number of units	Mileage per unit [km/year]	Engine power [kW]	Range [km]	Battery capacity [Wh]
Electric scooter	*Model1*	*Manufacturer1*	10	2000	0.3	45	473.6
Electric bike	*Model2*	*Manufacturer2*	10	3000	0.25	70	360
Electric pick-up vehicle	*Model3*	*Manufacturer3*	1	30000	10	201	19200
Electric pick-up	*Model1*	*Manufacturer1*	1	15000	5	135	14400

Table 31 Technical specifications and usage per year of the electric vehicles purchased to replace some diesel vehicles by an Adrigreen partner.

According to this case study, each year diesel vehicles emit about 7.8 times the CO2 released to produce the electricity absorbed by the substitute electric vehicles (Figure 28).

Local emissions of airborne pollutants such as NOx and Particulate Matter (PM) are assumed to be zero for the electric vehicles. However, as already stressed, the emissions of some pollutants, mainly greenhouse gases should be considered according to the location of the production site and on the technology used for producing electricity. Finally, also emissions due to wear of mechanical parts, brakes and tires of electric cars should be considered.

Anyhow, the use of diesel vehicles and machinery results for sure in much higher local emissions of CO2, NOx and PM (Figure 28 and Figure 29).

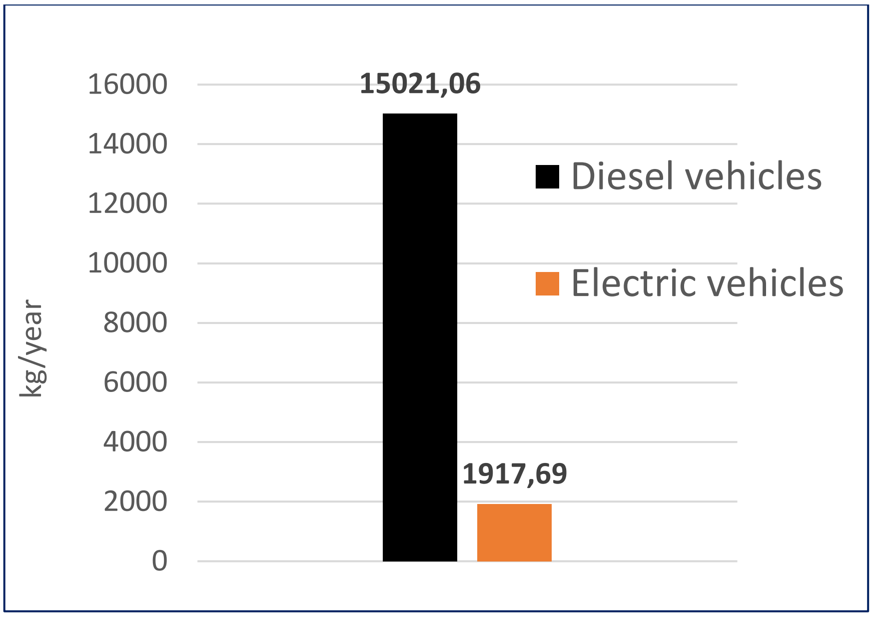

Figure 28 Comparison between greenhouse-gases emissions per year due to electric vehicles and the former diesel vehicles an Adrigreen partner.

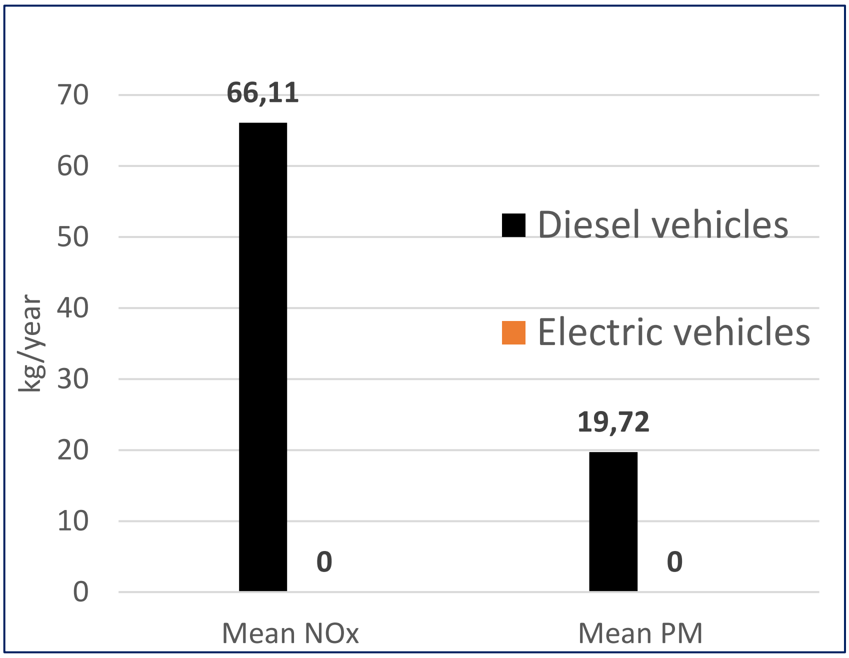

Figure 29 Comparison between local emissions per year of airborne pollutants (i.e., NOx and PM) due to electric vehicles and the former diesel vehicles at an Adrigreen partner. Emissions due to wear of mechanical parts, brakes and tires of electric cars were not taken into account.

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