LIFE Project Number

# LIFE02 ENV/GR/000359

# LAYMAN'S REPORT

Reporting Date

**15/03/05**

LIFE PROJECT NAME

# Improvement of Urban Environment Quality of Air and Noise Levels by an Integrated, Cost Effective and Multi-Level Application of Clean Vehicle Technologies IMMACULATE

Data Project

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|---|---|---|
| **Project location** | | |
| **Project start date:** | 01/09/2003 | |
| **Project end date:** | 31/08/04 | **Extension date:** 28/02/05 |
| **Total Project duration (in months)** | 24 months | **Extension months** 6 months |
| **Total budget** | 1.273.000 € | |
| **EC contribution:** | 570.000 € | |
| **(%) of total costs** | 44.77 | |
| **(%) of eligible costs** | 50 | |

Data Beneficiary

| | |
|---|---|
| **Name Beneficiary** | Centre for Research and Technology Hellas / Hellenic Institute of Transport |
| **Contact person** | Dr. Evangelos Bekiaris |
| **Postal address** | 6th km. Charilaou-Thermi Rd., PO Box 361, 57001, Thermi, Thessaloniki, Greece |
| **Visit address** | 6th km. Charilaou-Thermi Rd., PO Box 361, 57001, Thermi, Thessaloniki, Greece |
| **Telephone** | +30-2310-498.265 |
| **Fax:** | +30-2310-498.269 |
| **E-mail** | abek@certh.gr |
| **Project website** | http://immaculate.ece.ntua.gr |

## Project scope and objectives

It is widely accepted today that the severe environmental effects of vehicles as well as the great dependence of road transport on fossil fuels have stimulated the development and introduction, especially in urban environmental of new means of transport in the form of "clean" vehicles, mainly pure/hybrid electric vehicles (both 4-wheelers and 2-wheelers) and natural gas vehicles. These vehicles have proven in practice that they can contribute significantly to the reduction of air pollution and noise levels, while maintaining a moderate energy consumption.

The IMMACULATE project aim was to demonstrate the positive effects of the use of clean vehicles in the urban environment of Thessaloniki, Greece's second largest city and a major business and trade centre of the Balkans. It is notable that never before have such vehicles been introduced in the city, having a population of around 1 million people and experiencing a great degree of urbanisation. It was therefore the project's objective to demonstrate possible contribution of clean vehicles for mitigation of air pollution and excessive noise levels in the city by performing pilot tests with a small fleet of clean vehicles.

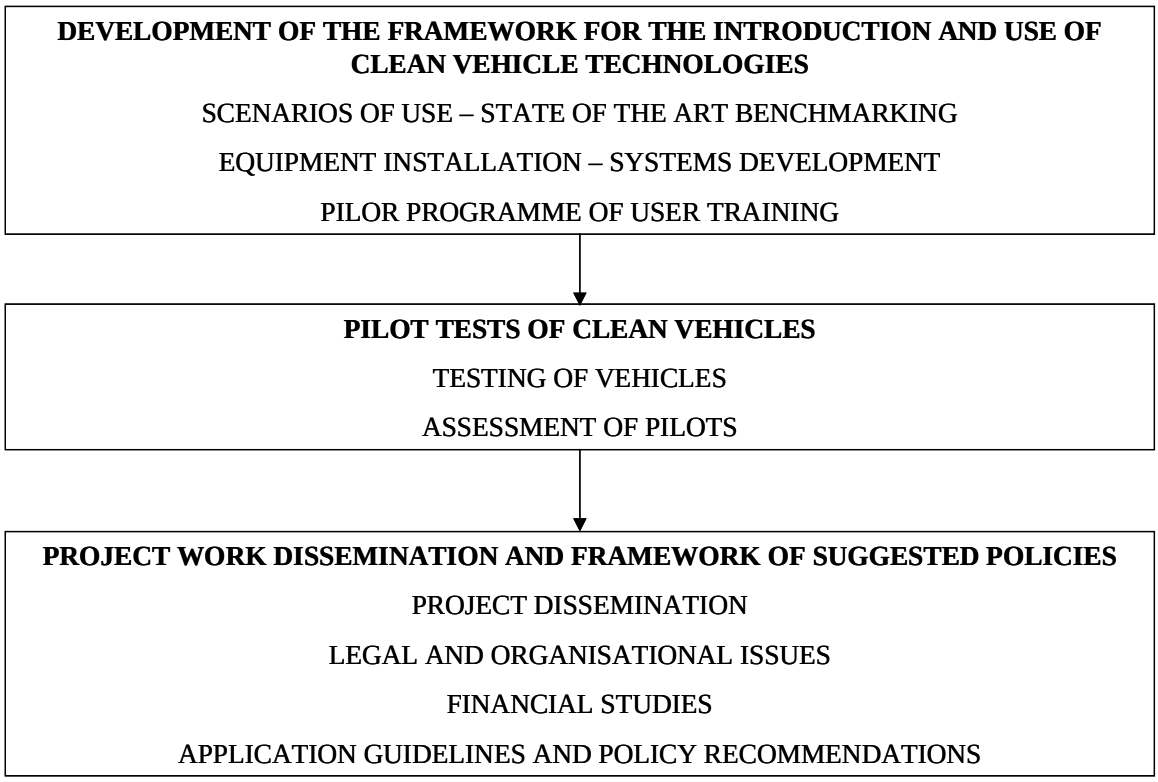
IMMACULATE has resulted in the demonstration of an innovative approach for the mitigation of air pollution and noise problems in the city of Thessaloniki – with a projection to other European cities – through the introduction of a system based on the combination of clean vehicles and advanced transport telematics and management technologies. Furthermore, through its dissemination activities and pilot studies, IMMACULATE has worked towards formulation of an "eco-consciousness" in the citizens of an urban environment, such as the city of Thessaloniki. It has also contributed towards standardisation and policy recommendations, especially for Greece which significantly lacks the progress achieved in this sector across Central and Northern Europe.

## Project tasks

The IMMACULATE project consisted of the following 10 interrelated tasks:

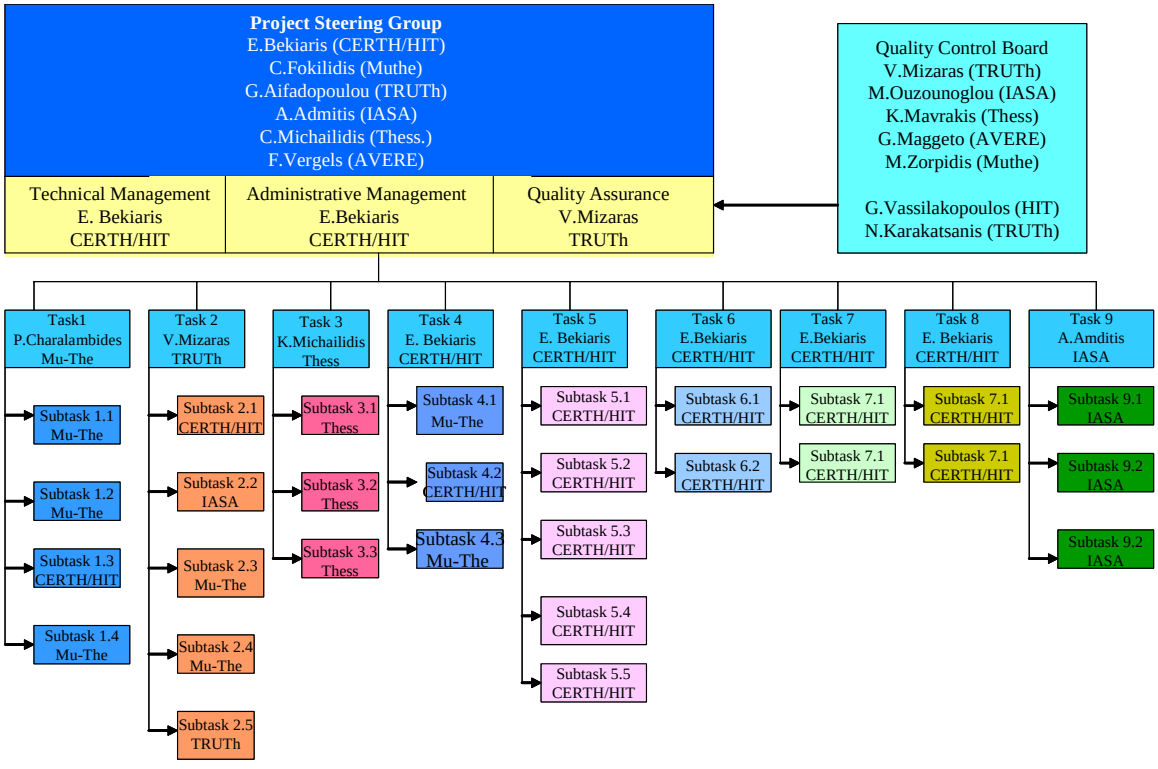
1. Scenarios of Use and State of the Art Benchmarking
2 Equipment Installation and System Development
3 Impact of User Training
4 Pilot Application
5 Pilot Assessment
6 Legal and Organisational Issues
7 Cost Benefit Analysis (CBA) and Cost Efficiency Analysis (CEA)
8 Application Guidelines and Policy Recommendations
9 Dissemination
10 Project Management

The project was implemented in three phases, as presented below:




## Management structure

The organigram of IMMACULATE project is presented below.




A Project Steering Group consisting of one person from each partner and led by **Dr. E. Bekiaris,** the project coordinator, was responsible for all major decisions concerning the

execution of the project. Three specific persons led the management activities of the project:

- *Dr. Evangelos Bekiaris* (CERTH/HIT) was the coordinator, **Administrative and Technical Manager** of the project.
- *Mr. Vasilis Mizaras* (TRUTH) was the **Quality Manager**.

The Project Quality Control Board (PQCB) was responsible for the assessment of the quality of the project's activities and deliverables. Each deliverable was reviewed by two partners and an external expert.

## Description of the techniques/methodology implemented and the results achieved

Work started with an analysis and quantification of the transport related air quality and noise problems in the city of Thessaloniki. The findings of this analysis indicate the following:

- There is a large penetration of private cars at the city, with approximately 30% of the population owning a private car. Most of the car owners prefer to use their car for their trip.
- By far, most of the trips are made to the city centre.
- Most of the non-private car users use the bus, the percentage being higher in the west areas, including the old city, thus revealing the specific importance of public transport for these areas.
- The routes with the greater traffic volume are mainly those around the city centre such as Egnatia Rd., Tsimiski, Rd. and Vas. Olgas Avenue. The roads to the city centre present the highest congestion levels (and thus emission levels), especially during the morning and early afternoon hours, when people go to work, therefore it is important to have clean vehicles being used by working people.
- The shortage of parking spaces, especially at the city centre, reveals the need to support the transport system with a mobility management scheme. Free parking can therefore be a tool for the promotion of clean vehicles.
- The statistical analysis shows that for a wide penetration of clean vehicles at a mass scale, mainly people at the outer area of the city should be targeted.
- The pilot introduction of clean vehicles, as this is envisaged in IMMACULATE, can address users of car rental companies, as there is a large and of generic nature number of users using one specific vehicle, mainly for work and entertainment.

An analysis of measured emissions around the city of Thessaloniki has shown that pollution in the North-West direction is mainly attributed to industrial activity, where as in the South (East and West) direction there is a great influence of urban activity, including motorisation. Furthermore, measured values of noise levels, reveal that major roads around the city centre present a high level of noise pollution.

Considering the specificities of the Greek market and the availability of such technologies, the following vehicles / technologies were selected and implemented:

- A hybrid electric vehicle, the Toyota Prius, which combines a 72hp thermal engine with a 45hp electric motor which can be supplied by the thermal engine and/or a NiMH battery of 274V.

- 2 electric scooters, that use a 48V battery for providing energy to a 1.5kW electric motor. They have a maximum speed of 45km/h and a range of approximately 50 km.
- 2 electrically assisted bicycles, that use a 36V battery, with which they can travel distances in the range of 55-65 km.
- 2 black boxes installed on the hybrid vehicle and on one of the scooters. This device is a programmable data recording system: electronic sensors are installed and perform various measurements, like distance, speed, acceleration/deceleration, foot brake occurrences, engine revolutions, period driven on thermal and on pure electric traction, etc.
- A GPS antenna-receiver was installed on the hybrid vehicle, so as to store the actual coordinates in an industrial PC.
- A fuel consumption meter was also installed on the hybrid vehicle so as to record actual energy consumption.
- An industrial PC was installed on the hybrid vehicle, so as to synchronise data obtained from the black box, the GPS receiver and the fuel consumption meter.
- An RFID tag and smart cards were implemented so as to authorise the hybrid vehicle's access to a specifically retained parking place.
- A portable emission analyser was used, so as to perform analysis of the emissions.

Figure 1: The Toyota Prius


Figure 2:The “Energy Monitor” inside the Toyota Prius

Figure 3: An electric scooter used in IMMACULATE

Figure 4: The electrically-assisted bicycles of CERTH/HIT

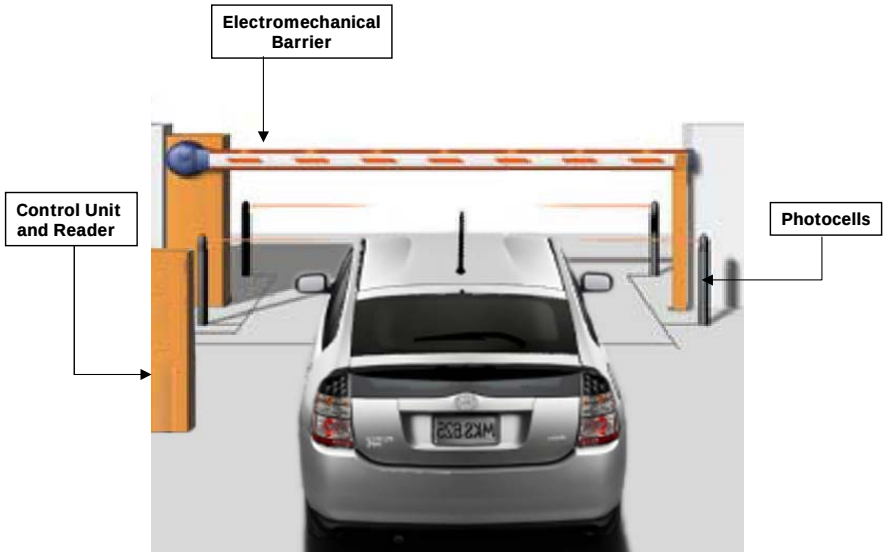



Figure 5: The installation for the parking of Prius at the centre of Thessaloniki (Halkeon Rd.), equipment parts (top) and realisation (end)

In parallel, a driver training scheme was developed, including detailed content, scenarios and a multimedia training tool, so as to promote the idea of "eco-driving". 30 drivers of various groups have been trained in the usage of the clean vehicles of IMMACULATE.


Figure 6: The introductory page of the 'clean vehicles' section of IMMACULATE multimedia tool

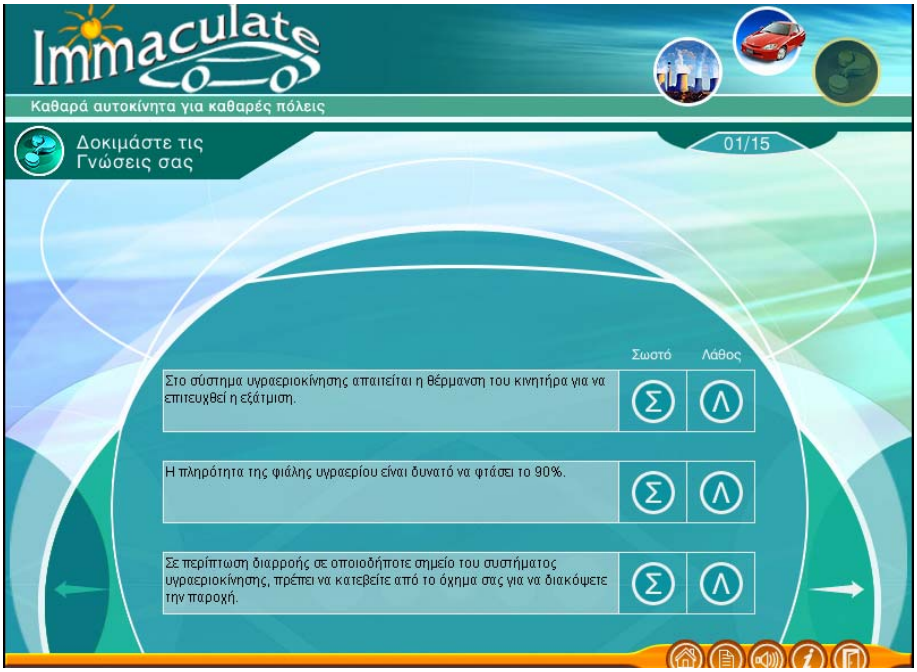



Figure 7:The introductory page of the 'test your knowledge' subsection of the IMMACULATE multimedia tool

The user acceptance tests had to address a wide public. Thus, a city car rental application was set-up, where the hybrid vehicle was rented to AVIS customers. In parallel, the vehicle was driven by other invited persons. During the pilot tests, 76 people have driven the hybrid vehicle. Only 2 out of 76 users had driven a clean vehicle before. After analysing the data collected during the hybrid vehicle application, it was found that 53.95% of users think that driving a hybrid car does not require any special familiarisation. 52.63% of users would surely use such a car and 38.16% say that they would rather use such a car. Only 1.32% of the users answered that they would rather not use such a car. Only 23.68% of the users would buy such a vehicle if it was 10-20% more expensive than a conventional car of the same category. The majority (55.26%) would only buy it if it had the same price. 19.74% of users stated that they would only buy it if it was cheaper than a conventional car of the same category. Users commented that there should be more incentives by the state, so as to better promote the use of such cars.

The electric scooters were given to the Motorcycle Association of Thessaloniki and to interested driving instructors. After a short ride, they were asked to express their opinion regarding the electric scooter. In the same way, the electric bicycle was given to the Association of Cyclist Unions of Macedonia-Thrace and to other interested persons, who were again asked to express their opinion after a short ride with the bicycle. During the tests a total of 53 users have driven an electric scooter and a total of 39 users have driven an electric bicycle.

As regards the scooters application, the scooter was well accepted by experts and users. Even people without an ecological conscience were enthusiastic about this new technology. A possible improvement could be that it is equipped with a bigger motor for heavy drivers and driving on slopes. Another problem is that, due to the lack of any noise, other traffic participants can not hear it and they have to detect it only through the vision, which may cause accidents. Various users questioned the cost to change the battery and the batter life. 1 out of 53 users would surely buy this scooter, whereas 41.51% of the users would buy it instead of a conventional one, under certain conditions.

As regards the bicycles application, the design of the electric bicycle makes the user believe that it is a motorcycle and not a bicycle. Besides, it is heavy and not adequate for cities like Thessaloniki, where the road network is not level but has various uphill / downhill segments. It is difficult to use it outside an urban area in Greece, due to the uneven ground morphology and the lack of special lanes for bicycles. However, 53.85% of the 39 users stated that they would buy such a bicycle, instead of a conventional one, under certain conditions.

A critical review of the Greek and European legislative framework regarding clean vehicles homologation, relevant promotion policies and further actions needed, according to the tests of the pilot, has taken place. It was found that incentives in various European countries mainly target electric or hybrid electric vehicles. Only in some countries does the legislation generally refers to “clean vehicles”, thus encompassing other types of technologies too. Regarding natural gas vehicles incentives mainly refer to low taxation in the use of natural gas as fuel. The European Commission has prioritised the use of biofuels, natural gas in the medium term and hydrogen and fuel cells in the long term and has proposed two directives regarding the use of biofuels. The USA legislation is much more complete and addresses all types of clean technologies. It refers in general to

"Alternative Fuels Vehicles" and gives various incentives both for the purchasers of vehicles as well as for the seller of fuel and the infrastructure provider.

As a conclusion of the experiences gained by the project, IMMACULATE has produced an "Applications guidelines handbook" on clean vehicles technologies.21 application guidelines were formulated, of which 6 are of general nature and refer to general planning process, 6 refer to enhancing the driver's comfort, 6 refer to reducing the total cost of the clean vehicle so as to become comparable to that of a conventional car and 3 refer to enhancing the awareness / acceptance of the public regarding clean vehicles technologies. 6 guidelines are existing ones, 7 are existing but verified by the findings of IMMACULATE and 8 are new, and have derived from the IMMACULATE findings, during the projects tests and surveys. These guidelines aim at assisting in designing an integrated support and intervention policy, so as to facilitate the wide introduction of clean vehicles into traffic, until they become competitive as far as market rules are concerned.

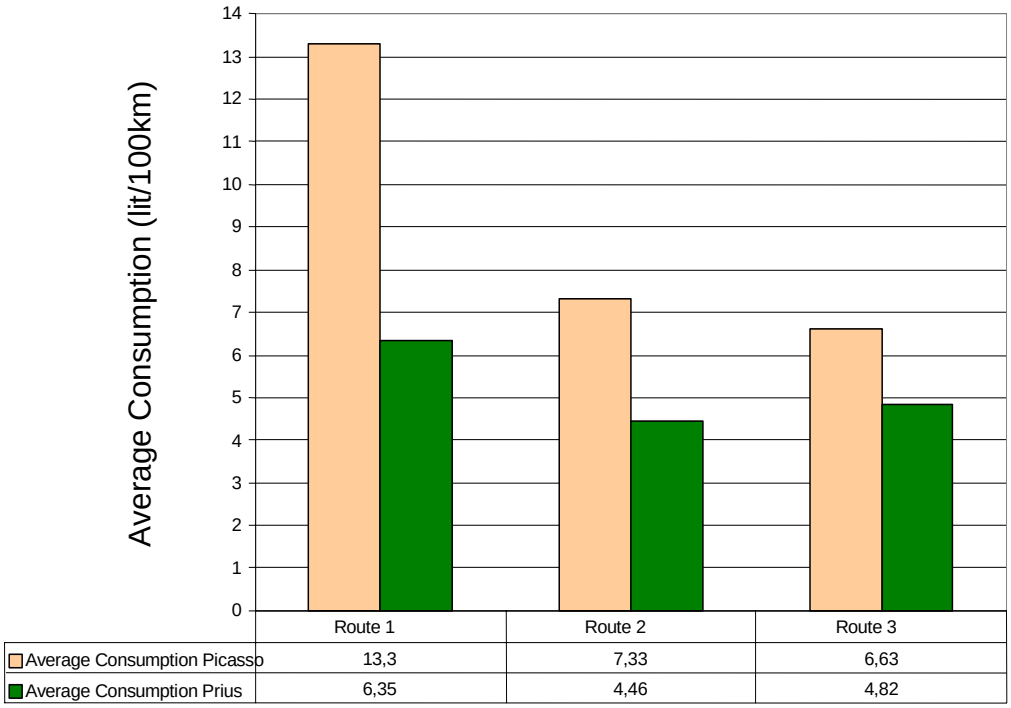
## Problems faced

During the project execution there was a significant delay in the implementation of the planned natural gas application due to the obligatory and time consuming procedures and authorisations that needed to be granted for the opening of the tender by the Municipality of Thessaloniki and legal and financial issues regarding the location and operation of the natural gas filling station. Furthermore, it was initially planned in IMMACULATE to build a natural gas filling station, suitable for the filling of one mini-bus of Municipality of Thessaloniki during the project life, which however would not be adequate for permanent normal operation. The Municipality of Thessaloniki however would not proceed with the purchase of the natural gas vehicle, unless a permanent station was built, that would be adequate and suitable for use even after the project end. Thus, negotiations started with the Public Gas Corporation (DEPA), so that they would co-finance the building of such a station in Thessaloniki. The discussions so as to formulate an acceptable by all partiers agreement for the building and operation of the natural gas filling station, plus the examination of possible legal implications, has unfortunately taken much longer than expected. There were constantly implications continuing to arise, i.e. it has been finally clarified that the owner would not be able to sell natural gas for private use. Because so much time has elapsed without any process in this issue, the natural gas application has been abandoned by the project, as the Municipality could not purchase a natural gas vehicle in case there would be no adequate filling station in the area.

## Assessment of the environmental impact of the project, describing the environmental benefits (illustrated with quantified information)

A technical evaluation pilot test was performed, so as to compare the performance in terms of fuel consumption and emissions of the hybrid car with that of a conventional car of similar cubism. The measurements were taken simultaneously from both vehicles at exactly the same driving conditions, since the two vehicles where moving together, one after the other. The following figure shows that the consumption of the hybrid vehicle is

in all cases lower than that of the conventional vehicle. The biggest difference is observed in the urban route.




| | Route 1 | Route 2 | Route 3 |
|---|---|---|---|
| Average Consumption Picasso | 13,3 | 7,33 | 6,63 |
| Average Consumption Prius | 6,35 | 4,46 | 4,82 |

Figure 8: Average fuel consumption per vehicle and route

There is a decrease in fuel consumption by the hybrid vehicle compared to that of the conventional vehicle in all three routes of the experiment. The reduction is 52% for a route in an urban area, 39% for a mixed route and 27% for a highway route. This is explained by the fact that within a city, the vehicle moves at lower speeds, thus the electric motor is activated, while outside the city the motor engine is used most of the time. Furthermore, when a conventional vehicle drives outside a city, its fuel consumption per kilometre is reduced. On the other hand, the hybrid vehicle's fuel consumption is not so much affected by the driving conditions.

Mean values of CO2 emissions for the conventional vehicle were measured from 14.02% for the highway route to 15.26% for the urban route, thus they were not depending much on the driving conditions. These values were much lower for the hybrid vehicle in all cases, namely 3.84% for urban route, 6.04% for mixed route and 8.67% for highway.

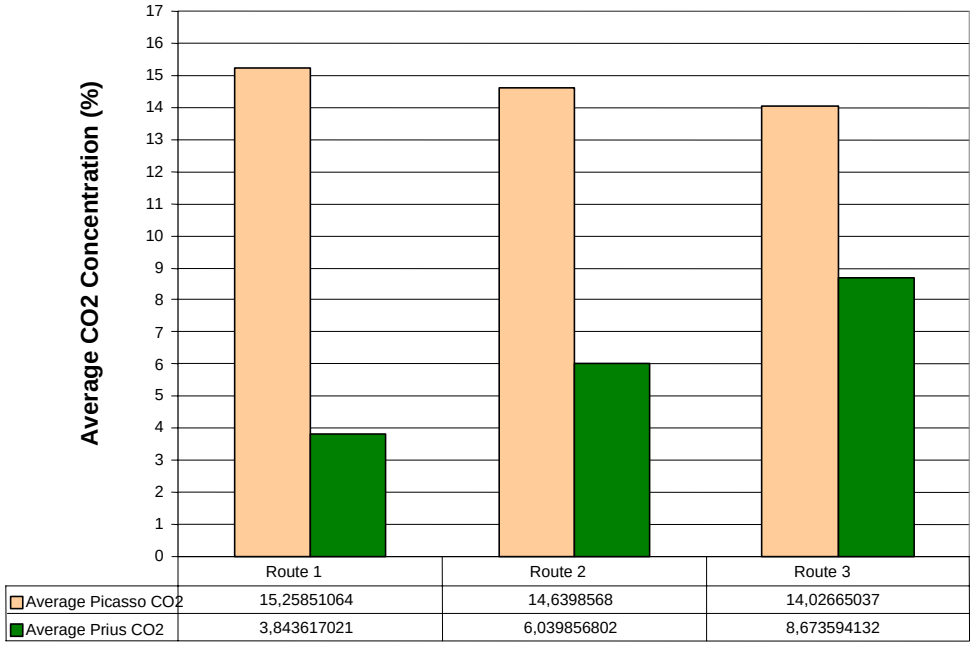



Figure 9: Average CO2 concentration per vehicle and route

## Cost-benefit discussion on the results (economic and environmental benefits)

An integrated policy of incentives is proposed, so as to achieve, on current prices, a reduction in the price of a new technology car of around 2,500 Euro seems to be a minimum required financial incentive. Such a reduction is around 8% to 10% of the vehicle price. Of course, by itself it is not enough to promote mass sales, since generally the price difference from conventional cars is 20% to 25%. However, if one considers also the economy due to the reduced fuel consumption, the economy in car life cycle due to exemption from circulation tax as well as the satisfaction of the owner due to the possession of a high technology product, for which one is normally prone to pay something more, it can be expected that such an incentive could activate the sales, initially at a limited level and then continuously increasing.

**Proposed Monetary Incentives include:**

Reduction of the taxable income of the customer by an amount equal to 30% of the price of the new technology car, equally distributed in 3 consecutive financial years (10% per year).

Return of part of the VAT, corresponding to 30% of the purchase price.

Exemption from any circulation restrictions in the urban areas, including any future toll fees for entering the city centre.

Exemption from financial obligations like testimonies of acquisition.

Especially for the urban areas of Attica and Thessaloniki, additional subsidy for the replacement of an overaged car (more than 15 years of age and with confirmed circulation during the last three years), with a new technology car, by 1,500 Euro.

The following table presents a possible five years scenario for the market entrance of new technology cars.

| **Year** | **Purchase of hybrid cars** | **Purchase of electric cars** | **Withdrawal of overage conventional cars** |
|---|---|---|---|
| 2005 | 1000 | 100 | 800 |
| 2006 | 5000 | 300 | 3000 |
| 2007 | 20000 | 500 | 12000 |
| 2008 | 25000 | 1000 | 20000 |
| 2009 | 30000 | 1000 | 25000 |
| **Total** | **81000** | **2900** | **60800** |

Table 1: Five year scenario for the market entrance of new technology cars with concurrent withdrawal of overaged cars

In any case, as usual when announcing incentives, the governments are committed for a certain number of purchases annually. This guarantees the adequacy of approved funds.

The following table presents an estimation of the financial burden created by the above incentives for the previous scenario. The total cost for the whole period of 7 years (5 years program plus 2 years exemption from taxable income) is estimated to 245 million Euros. 75 million Euros of these refer to refund of VAT, which would have not been levied anyway in case of purchase of conventional cars since they are around 30% cheaper. Therefore, this amount can not be considered as expense. The rest 170 million Euro are distributed to the tax exemption of the purchasers of new technology cars by 79 million Euro and to the subsidies for withdrawal of overage cars by 91 million Euro.

(The tax exemption was calculated to 350 Euro per annum and the VAT return to 900 Euro).

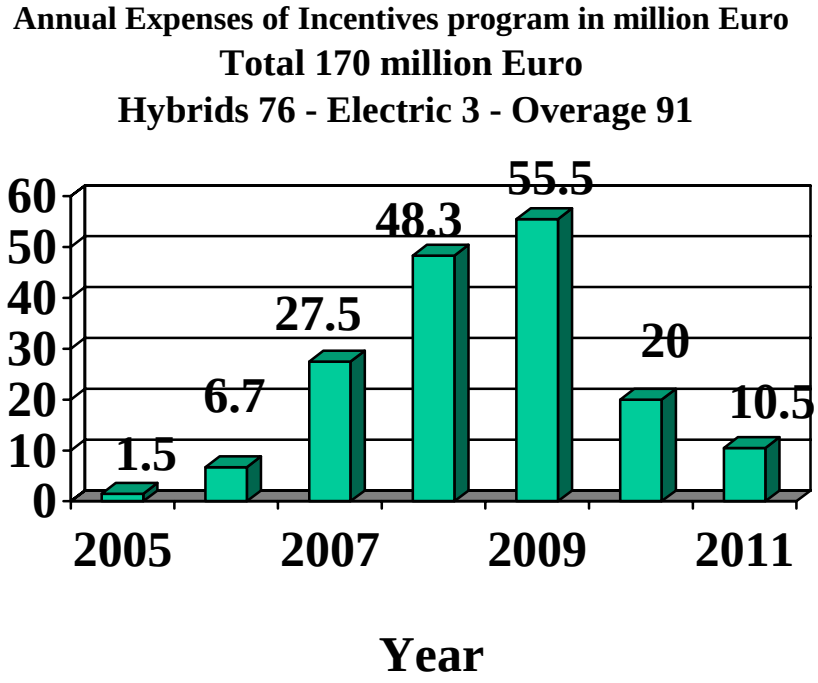



Figure 10: Annual expenses of the total proposed incentives program (in million Euro)

At the end of the time frame of the above scenario, there will be additional 83,900 clean vehicles in circulation in the areas of Athens and Thessaloniki, while 60,800 overaged cars will have withdrawn.

This fact alone is a significant benefit regarding environmental policy, as it will familiarise the public with the ecological vehicles and their advantages, as well as regarding international profile of the country which will prove that it participates effectively and innovatively in the efforts to preserve the environment and save energy.

Besides these benefits there are also measurable benefits. The new vehicles will consume on an annual basis around 30,000 tons of fuel less than the conventional ones (urban cycle), thus the emitted CO2 will be reduced by 72,000 tons. The imported oil will be proportionally reduced.

According to the following figure, currently Attica consumes around 1,250,000 tons of gasoline, while in 2007 this amount will be increased to 1,500,000 tons. The consumption in Thessaloniki at the same time will be 750,000 tons. The reduction of 30,000 tons corresponds to 1.3% of the total gasoline consumption in Athens and Thessaloniki in 2007 and correspondingly to the emitted CO2, which percentages are not at all negligible.

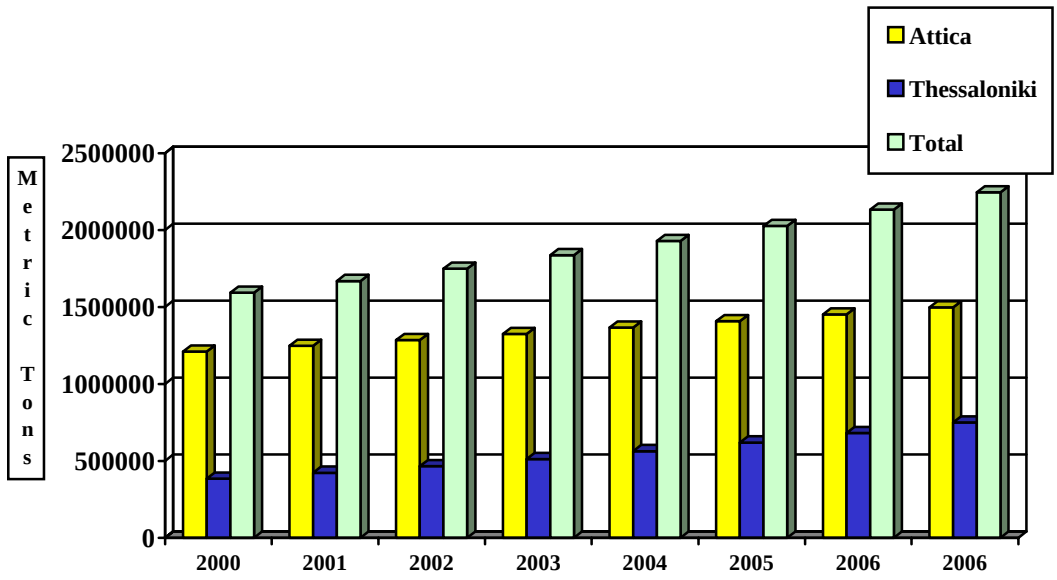



Figure 11: Gasoline consumption in Athens and Thessaloniki – Present and Forecast

The most important is however that the reduction of pollutants in the city centres are multiple times the reduction in fuel consumption because new technology cars in traffic jam conditions are zero-polluting cars, while conventional cars in such conditions pollute much more than in normal conditions. Of course there can be no comparison to overage cars of 15 and 20 years, which pollute uncontrollably in such situations.

Surveys of Italian researchers estimate that a zero-polluting car which replaces a car of the most modern antipolluting technology, leads during its life cycle to savings of 8,000 Euro to the national economy due to savings in expenses for restoration of damages and public health problems caused by pollutants and greenhouse airs emissions by conventional cars. Relevant studies from American researchers conclude to an amount of 17,000 USD. According to the most conservative Italian estimation, a hybrid vehicle replacing a non antipolluting vehicle aged 15 years or more (which emits pollutants 8 times more than a car of modern antipolluting technology) should save an amount equal to 25,000 Euro.

Even if one considers that the withdrawing car of 15 years age pollutes only twice as the car of modern technology, the savings will still be around 6,400 Euro. Hence, ***the savings for the national economy due to this reason is more than twice the total cost of the proposed monetary incentives.***

**Proposed Non Monetary Incentives include:**

- Free parking spaces. Such a measure can be locally offered by municipalities or by the state, in new self-financed parking lots, where their operation license may require a certain number of free parking spaces for clean vehicles. The relevant parking administration should be telematically performed, as in IMMACULATE, and may even be time-restricted, i.e. for 3 years after vehicles purchase.

- Free use of limited-access lanes, i.e. bus or Olympic lanes. Such a measure may be offered only temporarily, for few years, while the number of clean vehicles is very low and does not obstruct public transport. On the other hand, the behaviour of such vehicles may be mimicked by conventional vehicles, leading to increase in violations in the use of such lanes. Again, telematics may adequately solve the problem of police enforcement.
- Free access to inner-city limited areas. This has been already performed, by allowing the free circulation in the Athens inner centre of clean vehicles during the whole day. This could be widely applied, including pedestrian or other historic areas as long as such vehicles are few.
- Introduction of clean vehicles training in all driving schools, so that young people learn about the existence of such cars and benefits, as well as in schools, so as to appeal future drivers and gradually create eco-consciousness.
- Introduction of free re-training courses, 1-2 hours theory and ½ an hour praxis, on clean vehicles by manufacturers of clean vehicles for each new client or for a selected sample of those interested to purchase a vehicle.

**Specific market related** incentives, include:

- Obligation of all state authorities and municipalities to purchase only clean vehicles. The higher purchase cost will be balanced by gain in the operational costs.
- Promotion of the use of clean vehicles as taxis, like in Sweden. At least for Toyota Prius however, this requires a change in legislation, as currently taxis should be sedan-types of vehicles and Prius is a 5-doors model.
- Promotion of their use as driving school vehicles, however in such a case novice drivers would be trained on non-standard vehicles and may have difficulties to adapt later. Furthermore, only few new drivers wish to be trained on an automatic gearshift vehicle.

## Transferability of project results

The IMMACULATE project generally aimed at promoting the use of clean vehicles in an urban environment. This is of significant environmental value, since the emissions by conventional vehicles are a major cause of air pollution and noise in the cities. The IMMACULATE project was especially planned for cities in which new vehicle technologies have never before been applied, such as Thessaloniki, by conducting analyses of the general framework and the actions and means that need to be developed for the successful deployment of such technologies, as well as of the expected gains from such an initiative.

The IMMACULATE vehicle fleet, even though small in size, has been used to derive important qualitative and quantitative results (in terms of emissions and fuel consumption gains) of clean vehicles compared to standard vehicles for specific urban conditions. The IMMACULATE approach, that is the use of clean vehicles in combination with telematic support and mobility management schemes is **global**, in the sense that it can be applied anywhere across Europe and is being demonstrated in a local environment, that of the city of Thessaloniki. To this extent, the inclusion of AVERE, the major European organisation devoted to clean vehicles promotion, is important for the

diffusion of the developed guidelines and policy recommendations on a pan-European basis.

Thus, the IMMACULATE concept is global, but has been demonstrated on a local level. The activities realised in the project can be easily applied in other European cities of similar size. To this extent, the application in Thessaloniki was best suited to the purpose of IMMACULATE, as the city has never before been introduced to such technologies, nor had it the necessary infrastructure. IMMACULATE paves the way for the deployment of clean vehicles in a city and its example can also be applied Europe-wide. This was also one of the aims of the dissemination strategy of the project.