iCars Network	Intelligent Cars Thematic Network

D 4.3 Measurable objectives for ICT for energy efficiency

Author(s)	Wolfgang Reinhardt, ACEA
Project	iCars Network
Project Coordinator	Wil Botman FIA European Bureau Tel: +32 2 282 08 10 E-Mail: w.botman@fiabrussels.com

Abstract	This document represents the delivery WP 4.3 on a set of measurable objectives for energy efficiency
Keyword list	Eco-driving support, eco-traffic management, eco-demand & access management, eco freight & logistic management, eco-monitoring & modelling, ITS for new member states, energy saving aspects of ADAS, measurements & control.
Nature of deliverable	Report
Dissemination	Public

Project financially supported by
cip competitiveness and innovation framework programme 2007-2013 — European Commission Information Society and Media

Table of contents

1. Introduction

The report (ICT for Clean & Efficient Mobility) states that if all potential "Green" ITS measures are implemented together and within a long-term concerted European programme supported by all stakeholders, then an overall reduction of fuel consumption and CO2 emissions in the order of **25%** is achievable.

The third deliverable of WP 4 is to develop a set of measurable objectives, to be agreed upon among stakeholders, which leads to the overall objective of 25% improvement of fuel/energy efficiency as well as to identify areas where additional research is needed.
During the workgroup meeting on 26-27 of November 2009 in Brussels the group continued to discuss the structure of the final report as well as the input from the sub-project group leaders.
Main focus was on how the individual deliverables could be measured regarding its impact on energy efficiency for the agreed priority areas.
To measure progress in energy efficiency different drivers need to be identified first, before concrete measurements can be developed.

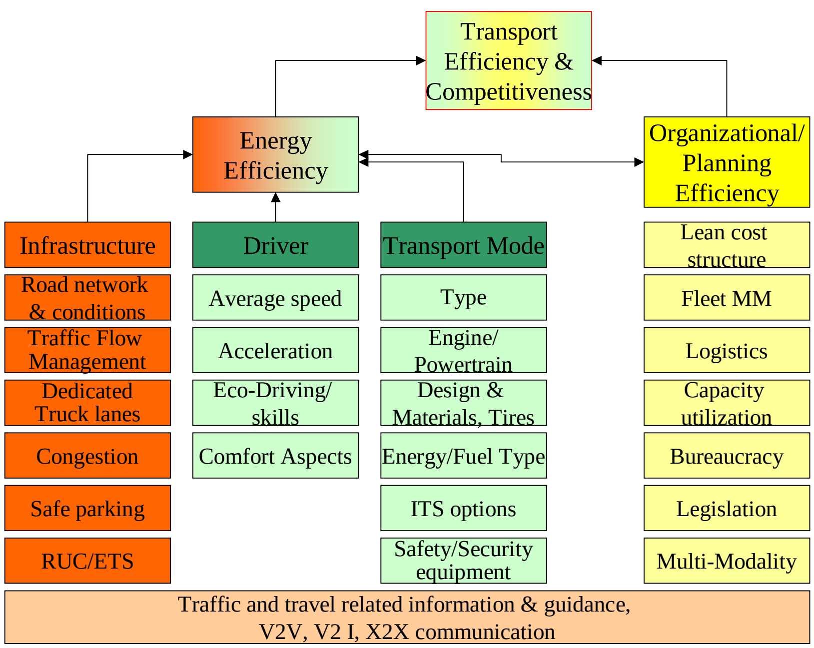


Fig.1: Drivers for transport efficiency

Energy Efficiency is a key part of Transport Efficiency. Organization Efficiency in the sense of productivity is the other main element. Only when a transport organization has a lean cost structure on a system level, is flexible to react on slumps/increases in demand, has a professional fleet management and purpose-built transport infrastructure with hubs and storage capacities where needed, trained and skilled drivers and employees, an optimal well maintained fleet structure (purpose-built types, age, capacity), a professional IT supported logistic management to secure a highest possible load factor, avoid empty drives, provide optimal routing support and cooperates with other traffic modes to best meet private and commercial customer requirements concerning travel/transport time and cost, it creates a solid basis to succeed in a highly competitive market. It also provides the possibility to save fuel through optimal route planning and support. Fleet Management and logistics are an integral part and applications of a modern ITS concept.

In addition to organizational efficiency the transport company has two more variables to influence: (a) a modern vehicle/transport means park with fuel efficient, environmentally friendly, safe and connected (responsive and interactive) vehicles/transport means and (b) skilled, environment conscious and trained drivers/operators. Fully electric vehicles are currently considered the cleanest option due to zero local emissions and potentially low greenhouse gas emissions[1] (in particular when energy is produced from renewable energy sources) but requires huge investments in R&D, especially in battery technology, and a significant cut in cost enabling competitive and affordable vehicle prices.
The more vehicles that are equipped with ITS options to help to avoid accidents, congestions and traffic jams, to assist drivers in critical situation, warn of dangers, maintain a high level of security and maintain a steady traffic flow by providing accurate, timely and dynamic information the higher the positive impact on energy efficiency.

Another but independent factor is the general transport infrastructure, which is operated by public and/or private operators. A poor infrastructure with bad roads, tracks, channels, poor signalling, many stops (junctions, traffic lights), dangerous curves, black spots, lack of safe parking places, etc. creates congestions, traffic jams and accidents, which then leads to unnecessary fuel consumption and CO_2 emissions. For electric vehicles a smart fuelling infrastructure needs to be established, to lessen the anxiety for the drivers to be stranded with the vehicle without enough electricity in the battery to reach the next charging point.

The challenge of the work of WP 4 workgroup is to identify the driving factors with the highest impact on energy efficiency, try to quantify the effects in a timely order and propose measurements to control the progress.
Due to limited budget the project has to concentrate on road traffic & transport and on more efficient applications for energy efficiency in the priority areas proposed under deliverable 4.2 such as:

- Eco-driving support,
- Eco-traffic management,
- Eco-demand & access management,
- Eco-freight & logistic management,
- Eco-monitoring & modelling.

[1] ELSA (Discussion paper): EC ICT for Transport, 4.9.2009

But, it is also strongly recommended to evaluate the impact of a combination of traffic modes (with regard to travel/transport time, consumption and costs) versus a mono transport means approach.

2. Measurements for Eco-Driving

To measure eco-driving it is necessary to differentiate between public, commercial and private traffic as well as between fossil fuels and other types of energy sources.

Eco-Driving should not be confused with co-modality where a person uses different transport means to come from A to B in an optimised way (time, costs). It also has nothing to do with selecting a different route or adjust the road infrastructure (less stops, etc.).

Eco-Driving, furthermore, is not about reducing emissions but to use the energy in a more efficient way. As CO_2 emissions are practically in a linear dependency from fuel consumption any reduction in fuel is also a similar reduction in CO_2. This, however, is not valid for pollutants like NOx, NO_2, particulate matters, etc. Pollutants could increase with less fuel consumption based on technologies applied.

Eco-Driving is in particular a very powerful tool to reduce the fuel consumption for a standard vehicle with only an internal combustion engine. The positive fuel reduction effect reduces slightly with a higher penetration of hybrid vehicles and perhaps with fully electric vehicles, especially when frequent braking is needed to regenerate energy. In addition, electric vehicles require energy, which needs to be produced by central power stations. The overall energy balance, therefore, depends very much on the efficiency of energy generation and with regard to emission what kind of energy source is used. Best for the environment is the use of clean (e.g. nuclear) energy and/or an increase in renewable energy sources.

How to measure progress by applying the principles of eco-driving?

2.1 Public Transport:

Transport of people (urban and rural areas) is related to **person - kilometre per unit of energy** (e.g. petrol or diesel or kilowatt). How many persons can be transported on how many kilometres with one unit of energy?

In other words, when a bus is fully loaded with e.g. 50 persons (within its weight limitations) it might consume e.g. 40 litres diesel per 100 km on a given route. With 1 litre the bus drives 2.5 km and transports 50 people on a given route. When the bus is only half full (25 people) the bus consumes less and might run 3 km with 25 persons on 1 litre of fuel. In the first example the factor is 125 (50 persons * 2.5 km). In the second example the factor is only 75 (25 * 3).

Eco-Driving now means that due to driver influence the mileage driven on a given route with one litre of fuel (diesel) gets more (50 * 3 = 150).

The report stresses the importance of applying the golden rules of eco-driving like driving not faster than 80 km/h (keeping the speed limits), keep vehicle rolling, avoid unnecessary stops, do not idle more than 1 minute, when slowing down leave the throttle and let the bus drift the engine instead of braking away the kinetic energy, try to keep the same gear as much as possible, check tire pressure regularly, try to warm up the engine before driving, etc.

To check and/or prove the effect of eco-driving a **number of field tests** are the most appropriate measurement. Measure the fuel consumption before eco-driving training and after. Then repeat the measurement several months later to distinguish between training effect and sustainable change. Measure the eco-driving effect under different driving conditions and on different routes (make sure to notice the weather and other surrounding parameters that greatly influence the fuel consumption so that the effect from eco-driving can be statistically proven). The collected information can then be used to feed a simulation model in order to calculate the overall impact in percentage of fuel reductions, quantify the information using average figures (mileage driven and average fuel prices) to arrive at an overall economic figure in Euro or percentage of GDP. Overall fuel reduction can be transferred into $C0_2$ reductions in bn tons.

As in particular electric busses would depend on regenerative energy (e.g. by braking) eco-driving principles may contradict this technical requirement.

Recommendation: Initiate eco-driving test (for trucks and busses), consolidate existing eco-driving research and experience, develop simulation model to quantify the impact on energy savings for Europe.

2.2 Freight Transport

In **commercial freight transport the measurement is in tons-kilometre per unit of energy** instead of persons-kilometre. How many tons can be transported on how many kilometres with one unit of energy? The principle is practically the same as explain before with busses. The impact of eco-driving could be measured in the same way. In addition, fleet management constantly **measures driver's driving behaviour by fuel bills, average consumption figures** per transport means and assigned budgets. The correct measurement, however, needs to take into account the tons of transported goods, as otherwise empty driving would be honoured.

To give an idea on the **potential** the work group tried to extrapolate the results from Sweden with a population of about 9 million people to EU-27.

If all the bus and truck drivers starts to drive more environmentally friendly and saved 5% (Drivec, 2007) of diesel in a longer term, then the fuel consumption could be reduced by 160 million liters per year. This would lead to a CO_2 reduction of 405 000 ton per year. The saving would be 150 million Euros (Drivec & Swedish Road administration, 2007) just for Sweden.
As EU-27 has a population of 500 million people (Foundation Robert Shuman, 2009) an extrapolation would give a saving of 23 000 000 ton CO_2 per year and 17 778 million liters diesel. The money saved would be 16,7 billion Euros. It is, however, questionable if the population figure could be taken as a reference due to different consumption patterns in the different countries.

Instead of the population approach, another assessment could be by using the number of busses and trucks.
For busses alone the calculation would be as follows:

In the EU-27 there are (2002 figures) around **890 000 buses** (UNECE, 2008). The models and the type of the busses vary from country to country leading to different fuel consumption. If we continue assuming that the average fuel consumption for a city bus is around 4 litres per10 km then the total amount of used fuel in the bus sector can be estimated of 56,960 million litres (using that a bus drives 250 km/day during 320 days/year). An Eco-Driving course gives in average a 5% fuel reduction for a longer term.
By using the two numbers the EU-27 bus fleet could **reduce the fuel consumption by 2 848 million litres p.a.**

Recommendation: Try to do a similar analysis with number of trucks

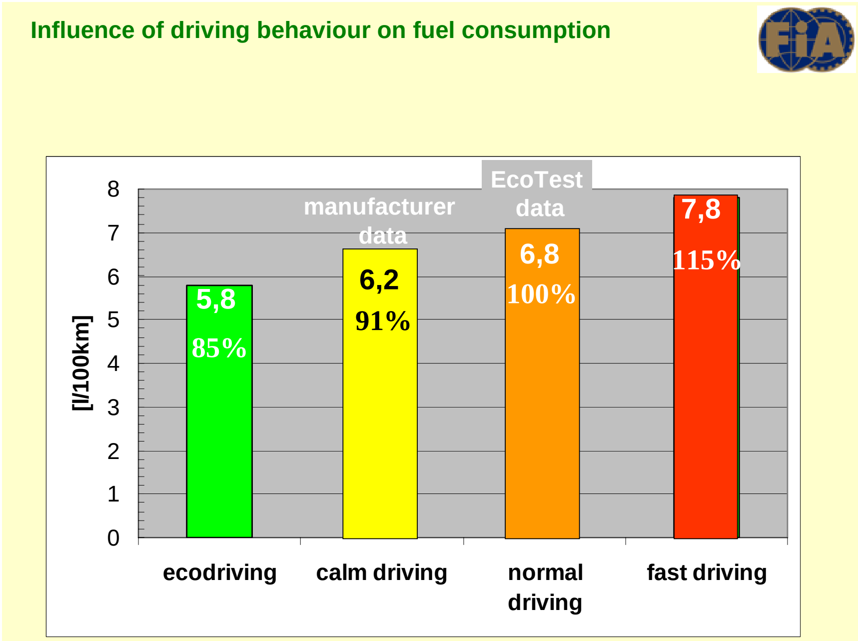
2.3 Private Transport

For **private fossil fuel powered or even hybrid (plug-in hybrids) cars** (with limited seat capacity) the **petrol or diesel bill** and the related **average fuel consumption per 100 kilometres** is the accepted measurement.

Again, to arrive at overall saving potentials by eco-driving it is advisable to carry out **tests with the same persons on the same cars and driving on the same route before and after eco-driving training** to measure the short-term and long-term training effect. It is obvious that a long-term sustainable change only happens when drivers basically change their driving behaviour and become more conscious about fuel efficiency and environment. How to change user behaviour is not part of this report.

Furthermore, **support devices** like gear indicators, start & stop automatic, visual warning signals **should be tested in the same way but one device/application at a time**. Through in-depth interview with test persons the most accepted device could be selected for more intensive testing. Afterwards, a simulation model could lead to an overall economic impact and the selection of priority devices. It, however, is doubtful that the results will be unique, as test conditions across Europe will probably deviate from each other so that a range of results is more feasible.

The following chart shows the differences between different driving styles.
When a particular car is driven in a normal driving style the car consumes 6,8l/100km. Following the rules of Eco-Driving, and applied during clubs' training courses, the consumption is reduced to 5,8l/100km. This corresponds to a reduction of 15%.
With a fast driving style the consumption increases to 7,8l/100km. This is an increase of 15%. These figures clearly underline that driving behaviour has a great impact on the average consumption of a vehicle and its related (linear) CO_2 emission.



To show the potential, a 7% sustainable average saving is equivalent to approximate annual savings in EU-27 of 16 bn litres of petrol/diesel (> 20bn Euro p.a.). (250 million Vehicles, 12.000 km p.a., 7.5l/100km, 7% sustainable saving, 1 litre= 1,30 €).

3. Traffic Management

3.1 Traffic Throughput

Concerning **ICT/ITS applications for eco-traffic management** it is important to separate between infrastructure-related and organizational measures.

Under infrastructure we need to first exclude building measures like building new roads, road repair, elimination of black spots, straightening of roads, mitigation of sharp curves, installation of crash barriers, installation of more traffic signs and speed cameras, adding dedicated truck lanes, providing additional parking places for trucks, etc. as they have nothing to do with ICT and ITS. The same is valid for radio broadcast of traffic information (point to all).

Intelligent infrastructure collects and provides traffic flow relevant information to the driver (point to point) either directly or via traffic management centres (point to multi-point). More sophisticatedly, intelligent infrastructure does not need to be stationary but could be mobile, could be a vehicle or a mobile device and sends and receives information (sender and receiving hardware and software). In the future, data transfer will probably not be “either or” but complementary.

The **objective of a professional traffic management is in first instance to keep the traffic moving**.

Therefore, it can be **measured in traffic throughput between two reference points** on a given route and at a given time (in- and output analysis of number of vehicles and average time used to drive from point A to point B). It makes sense to measure traffic throughput at peak times and in urban or metropolitan areas as a starting basis.

Traffic throughput is influenced by number of vehicles running from A to B, the number of vehicles joining from side roads, starts & stops at traffic lights and/or junctions, accidents, break downs, weather conditions, etc.

ICT related measures are RDS-TMS, Variable Message Signs, Traffic Light Synchronization, ramp up metering, timely opening of parking lanes for traffic, different road usage fees at different times or access restrictions, blockage of roads or deviations based on traffic density, congestion, incidents and fluidity, etc.

Most important success factors are accurate, real-time and dynamic information.

As start & stops, idling time, etc. increases fuel consumption (energy consumption in general) **any measure to keep traffic flowing has a positive influence on energy efficiency.** How high the impact, however, will be depends very much on the respective situation and **can only be measured by field operational tests** (e.g. Telefot). Such tests should reflect different situations with a given composition of vehicles (reflect vehicle park structure) at different times as a basis for a simulation model.

Depending on the individual impact of a single measure and its regional and national potential an extrapolation can then be carried out.

3.2 Sub-Project: Eco-Traffic Management (Lindholmen / ISIS)

It is estimated that traffic congestion costs about **1-2% of the European GDP**. It also leads to extra fuel consumption and thus CO2 emissions.
Optimised traffic flow management & control helps to improve road safety but also contributes to clean & efficient mobility as improving traffic flows leads to shorter journey times and lower average fuel consumption.
Parking guidance and information systems can reduce average search time for a parking place in a city by 50%. As about 30% of local traffic is related to searching for parking the saving potential is enormous.
In urban areas, an increase in average speed dramatically reduces fuel consumption. E.g. traffic light synchronization has the potential to increase intersection throughput for private traffic by 15%. In another project, public transport, which was given absolute priority, showed a speed increase by almost 20%. Variable message signs can guide traffic away from problem areas, optimise section speed and capacity and leads to up to 30% less accidents and up to 8% less emissions. When once cooperative systems allow communication between vehicles and infrastructure new applications will allow motorist to make more informed route choices.

3.3 Sub-Project: Eco-Demand and Access Management (ISIS)

Demand and Access Management have different focus but are both used to better manage mobility by directly reacting on demand for mobility while traffic management tries to optimise its supply.

Demand management describes measures to in influence the demand for transport and mobility.

Managing demand for mobility in an eco/efficient way requires an integrated approach and involvement of all relevant stakeholders, provision of reliable, real-time and dynamic information on alternative means and schedules (multimodality) and information on how they connect to allow the traveller (private and commercial) to go from A to B.

ISIS sees the potential of a 15% reduction in CO_2 through modal split alone and a total of **23%** with the help of ITS and incentives.

Access management helps to achieve the necessary balance between traffic movement in a city and accessibility by controlling access of vehicles to specific areas, with the aim to improve air and environmental quality. Famous examples for access management are London, Stockholm and Milan but other metropolitan areas like Rome, Frankfurt, Prague, etc. also have or are about to introduce similar measures.

Recommendation: Consolidate existing research, carry out further real-life tests and build simulation model to explore the overall impact on energy-efficiency in Europe.

4. Fleet Management & Logistics

4.1 Measurements

Concerning **fleet and freight management** the decisive factor is **profitability** described as the difference between the revenues obtained from output and the expense associated with consumption of inputs.

Under a cost centre accounting approach fuel-savings will directly influence the bottom line and contribute to higher profitability of the company.

For this reason in most cases individual trucks are taken as cost centres so that fleet managers immediately see the positive impact of ITS applications and progress in logistics and fleet management.

Energy-efficiency in fleet & freight management is measured in ton-kilometres per unit of energy. To distinguish between different applications like "heavy eco-driving", professional route and delivery planning, remote downloading of driving and transportation related data and information, paperless customs clearance, eco-navigation, ADAS equipment, etc. individual field tests need to be carried out to explore the potentials of reducing fuel consumption.

4.2 Sub-Project: ECO Freight & Logistic (Fleet) Management (ACEA)

A main concept that is recently taking shape is the one of "Intelligent Cargo". It intends to provide enhanced and widespread capability to monitor, trace and safely handle moving goods, increase the efficiency of transportation network by improving synchronization between logistic users, operators, and control authorities and to improve the sustainability.

ITS for fleet management includes the management of cars, vans and trucks. It can also include vehicle maintenance and financing, vehicle and driver dispatching, Telematics services, driver time and shift management, fuel monitoring and management and health & safety management.

A recent study, the SMART 2020 Report argues that through a host of efficiencies in transport and storage, smart logistics in Europe could deliver fuel, electricity and heating savings of 225 Mt CO_2 equivalent. On a global level this number would sum up to 1.5 Gt CO_2 equivalent, **equal € 280 billions.**

Recommendation: Exchange of best practices, field tests and simulations

5. Eco-monitoring and modelling (ISIS, AMANOVA):

This topic is horizontal in the sense that it is not an end service.
The focus is on a description of general statistical methods of traffic modelling. Consequently, only non-parametric statistical approach has been considered, while specific parametric methods have been omitted. Similarly, description of problems related with adaptation of the proposed methods to specific information processing and transmission devices and estimation of information cost have also been omitted.
Since the complete non-parametric model stems from recorded data it is rather generally applicable. In spite of the complexity of roads traffic phenomena, non-parametric statistical modelling of relations between characteristic variables by conditional average estimator appears quite promising for generation of new information. Demonstrated examples indicate that this method can be simply utilized in prediction of traffic field distribution and related variables such as path integral of traffic activity and an optimal travelling time interval. It could also provide information about possibility of congestion development in the selected travelling time interval, etc. Beside this, non-parametric approach renders possible a simple joining of weather and traffic data and related prediction of critical driving conditions and states on roads. Related to the modelling of traffic activity field is also the modelling and forecasting of pollutants generated by the traffic and development of devices for this purpose. The information generated by such a treatment can be simply transmitted to participants in the traffic over existing communication devices such as mobile telephones or Internet. An important advantage of non-parametric statistical modelling is that the governing algorithm can be formulated rather generally and executed practically automatically without essential modification at its adaptation to a specific case. It also permits a simple inclusion of control variables into the description. Consequently, the non-parametric statistical modelling provides also a basis for an optimal control of traffic by ITS. Its utilization renders possible inclusion of quantitative energy efficiency and eco driving measures into objective function used in development of optimal traffic control. For this purpose a standalone intelligent traffic sign could be developed that could provide for a simple prevention of congestion development on selected sections of highways based upon predicted properties of traffic flow. At present it seems that about 15% of traffic congestions on highways in Slovenia could be reduced in this way. In addition, comparison of really measured traffic flow with the predicted one provides a basis for quantitative estimation of energy efficiency changes.

Recommendation: Intelligent traffic flow predictor should be introduced in traffic management and control centres and service stations as an additional computer driven support of decisions about proper actions as well as a source of information about traffic activity in the future for traffic participants.

6. Active & Preventive Safety

In addition to the above mentioned priority areas **non-ICT related measures of new safety devices like Advanced Driver Assistance Systems (ADAS)** has been investigated by a sub-workgroup led by FIA.
European Automobile Clubs have done research on the impact of ADAS and other safety systems to shed light into how useful additional safety systems are with regard to accident avoidance and energy-efficiency.

The figure below show different safety applications and their estimated accident reduction potential taken from two different sources: eImpact and ADAC.

Accident avoiding potential of individual ADAS (penetration rate estimated for 2020)

		eIMPACT		ADAC				
		improvement potential total	improvement potential MW	improvement potential total	improvement potential EU+IU	improvement potential EU+IU	improvement potential MW	improvement potential MW
stability control	ESC	14%	14%	8500	7990	2,5%	510	2,6%
full speed range	FSR	1%	1%					
emergency braking	EBR	1%	1%	12000	10560	3,4%	1440	7,2%
pre crash vulnerable	PCV	1%	0%	500	500	0,2%		
lane change assistant	LCA	1%	1%	2900	2726	0,9%	174	0,9%
lane keeping support	LKS	3%	3%	7900	7426	2,4%	474	2,4%
night vision warning	NIW	1%	0%	500	500	0,2%	0	0,0%
driver drowsiness warning	DDM	1%	2%	11000	9020	2,9%	1980	9,9%
e-call	ECA	4%	4%					
intersection safety	INS	0%	0%	9700	9700	3,1%	0	0,0%
wireless local danger warning	WLD	1%	1%					
speed alert	SPE	5%	5%	6600	6204	2,0%	396	2,0%
automatic head light activation	AHA			19	19	0,0%	0	0,0%
adaptive head lights	AHL			438	438	0,1%	0	0,0%
runflat indicator	RFI			600	528	0,2%	72	0,4%
traffic information system	TFI			735	691	0,2%	44	0,2%
traffic sign recognition and alert				990	931	0,3%	59	0,3%
infrastructure based warning systems				1800	1692	0,5%	108	0,5%
intervehicle hazard warning				2700	2538	0,8%	162	0,8%
alcohol interlock				4025	3784	1,2%	242	1,2%
adaptive brake light				5600	5264	1,7%	336	1,7%
total		*33%*	*32%*		*70510*	***22,4%***	*5997*	***30,0%***

In the following chart the congestion reduction potential is estimated, based on the above given accident reduction figures. Out of these figures the CO_2 reduction potential is calculated.

CO2 emission reduction due to ADAS

total road traffic related CO2 emission p.a. (2006)	147.000.000	t
total number of accidents (with injuries)	335.000	accidents
CO2 emission per standing vehicle per min	56	g/(vehicle*min)
vehicle to vehicle distance in a congestion	8	m

	ExtraUrban+InnerUrban	MotorWay	remarks
accident share	94%	6%	ADAC
accidents = total numb. of accidents*accident share	314.900	20.100	accidents
accident reduction potential due to ADAS (%)	22%	30%	FIA/ADAC
acc. red. pot. due to ADAS = %*accidents	70.538	6.030	accidents
accident share creating congestions (%)	33%	100%	FIA/ADAC
congestion reduction due to ADAS = accident share*acc. red. potential	23.277	6.030	congestions
average congestion length	1.000	3.100	m
average congestion duration	30	85	min
average vehicle number within congestion = av. cong. lenght/vehicle to vehicle distance in cong.	125	388	vehicles
average CO2 emission per cong. = av. umnber of vehicles within cong.*CO2 emission per standing vehicle*av. cong. duration	0,21	1,84	t/congestion
CO2 emission reduction potential due to ADAS = av. CO2 emission per congestion*cong. red. due to ADAS	4.888	11.122	t
proportional CO2 emission reduction due to ADAS = CO2 emission red. pot. due to ADAS/total road traffic related CO2 emission p. a.	0,0033%	0,0076%	**0,0109% total**

The results show an overall reduction figure of 0,0109% of total road traffic CO_2 emission. That means, in spite of beneficial impact of ADAS on future traffic safety, the achievement for sustainable emission reduction is only marginal.
When CO_2 reduction is a linear function of fuel saving then the statement should be allowed that the ADAS systems mentioned above have a marginal impact on energy-efficiency as well.