Evaluation of energy saving measures in the transport sector: a review of efforts and certainty

Frederic Rudolph
Wuppertal Institute for Climate, Environment and Energy
Germany
frederic.rudolph@wupperinst.org

Susanne Böhler
Wuppertal Institute for Climate, Environment and Energy
Germany
susanne.boehler@wupperinst.org

Keywords
energy savings, evaluation methods, data collection, Directive on Energy End-use Efficiency and Energy Services, energy end-use efficiency, transport policies and measures

Abstract
The EU Directive on Energy End-use Efficiency and Energy Services (ESD) set an indicative target for EU Member States to achieve a 9% annual energy saving by 2016 from new energy efficiency improvement (EEI) measures. Until now there has been no common methodology on how to measure and evaluate such savings. An international consortium funded by the Intelligent Energy Europe programme and co-ordinated by the Wuppertal Institute has developed harmonised methods for the evaluation of end-use EEI measures. The European Commission encourages Member States to prove energy savings with the help of these methods.

From the evaluation point of view, the transport sector is a special case. In the transport sector, data collection appears to be difficult. A number of values can be derived from existing national statistics, but sources have to be analysed in order to be operational. In passenger transportation, measures prevalently aim at changing mobility behaviour. Mobility behaviour depends on specific socio-economic and local conditions and might therefore vary considerably from measure to measure. Often, only surveys that are well-defined for certain conditions can generate appropriate data.

The paper discusses availability and certainty of data sources to be derived to evaluate EEI measures in passenger transportation. It first introduces two transport-related bottom-up evaluation methods for the transport sector. One aims at evaluating measures fostering vehicle energy efficiency. The other one aims at evaluating modal shifts. The paper then points to sources of corresponding data and the way the data have to be analysed. Thereby it demonstrates the trade-off between evaluation costs and the level of certainty. In so doing, it gives recommendations how to conduct the evaluation of transport-related EEI measures with keeping both efforts low and certainty high.

Glossary

CEN	European Committee for Standardization
ESD	EU Directive on Energy End-use Efficiency and Energy Services
EEI measure	Energy efficiency improvement measure
NEEAP	National Energy Efficiency Action Plan

Introduction
The EU Directive on Energy End-use Efficiency and Energy Services (ESD) set the indicative target for EU Member States to achieve 9% of annual energy savings between 2008 and 2016. The savings target shall be the result of cumulative annual energy savings achieved throughout the nine-year application period in the residential, tertiary, industry, and transport sector. The ESD requires Member States to implement National Energy Efficiency Action Plans (NEEAPs) that contain a description of energy efficiency improvement (EEI) measures that are supposed to contribute to the achievement of the target. Moreover, the Member States shall monitor and evaluate the measures implemented in order to prove the achieved savings. The demonstration of their achievement shall be conducted by using top-down and bottom-up methods (Directive 2006/32/EC).

The European Commission financially supports the development of evaluation methods through the EMEEES project to support the Member States to effectively evaluate and monitor their EEI measures[1]. These serve as guidelines for the Member States how to prove the energy savings.

With respect to the transport sector, Annex III to the ESD gives information about the areas in which EEI measures may be developed and implemented. The list of transport-related examples refers to two strategic approaches:

1. Vehicle efficiency – The ESD lists the promotion of energy-efficient vehicles, the energy-efficient use of vehicles including energy efficiency devices, fuel additives which improve energy efficiency, high-lubricity oils and low-resistance tyres.
2. Shift to more sustainable transport modes - The ESD refers to commuting arrangements, car sharing, car-free days and other measures aiming at modal shifts from more energy-consuming modes of transport to less energy-consuming ones.

Therefore, methods have been elaborated to evaluate vehicle efficiency and modal shifts in passenger transportation. Their use demands the Member States to collect a number of relevant data in order to be able to quantify the energy savings. However, collection of transport-related data appears to be rather difficult, as the sector is characterised by large numbers of very small mobile units.

This is the starting point of the paper. It will discuss availability and range of data sources in the transport sector to be derived within evaluation. It will point to the trade-off between evaluation costs and the level of (un-)certainty. In so doing, it aims at giving recommendations how to conduct the evaluation of transport-related EEI measures with keeping both efforts low and certainty high.

EEI Measures in the Transport Sector

Sustainable transport is a general guidance in the current policy documents of the European Union (European Commission 2006). However, with respect to energy consumption and carbon dioxide emissions, many Member States have been failing to take action. Whereas the final energy consumption in the residential, tertiary and industry sector in the EU-27 has been stagnating or decreasing during the last two decades, energy consumption of the transport sector has been growing steadily (EEA 2008).

The political task is to provide mobility while reducing the negative impacts of transport. In theory, three strategic approaches have been identified to bring about sustainable mobility (e.g. SRU 2005):

- Avoiding transport needs: Reducing distances covered via spatial planning measures such as mixed land-use and linear settlement patterns.
- Shifts towards more sustainable modes of transport: Encouraging people to choose public transport or zero emission mobility and discouraging to use motorised transport.
- Vehicle efficiency: Improving transport technologies and occupancy levels as well as fostering eco-friendly driving behaviour.

In practice, national policy makers currently focus on the latter two strategies. It could be for this reason that Annex III to the ESD only refers to measures aiming at modal shifts and at vehicle efficiency. Consequently, the NEEAPs of the Member States stick to these latter two strategic approaches. The measures announced in the NEEAPs range from energy taxes and labelling schemes to the extension of railbound infrastructure and advertisement for public and non-motorised transport. Table 1 summarises important EEI measures listed in the 2007 NEEAPs. The measures are summarised into four important fields of application. The cells highlighted in grey indicate that the respective Member State aims at implementing at least one measure in the particular field. For instance, one important field of application is carbon taxes. 14 of 27 Member States have graduated or aim at graduating their taxes on car acquisition and/or car ownership by carbon emissions.

The ESD Evaluation Concept

For both the improvement of vehicle efficiency and modal shifts, top-down as well as bottom-up evaluation methods have been developed. The use of top-down methods to evaluate energy savings means that "the amount of energy savings or energy efficiency progress are calculated using national or aggregated sectoral levels of energy savings as the starting point" (Directive 2006/32/EC). Therefore top-down methods rely on top-down indicators. For example, the ODYSSEE project developed top-down indicators at the EU level and for most Member States for the last 15 years[2]. Top-down evaluation means then going down to more disaggregated data when necessary and correlating the realised energy savings with EEI measures (see paper 3270 Bosseboeuf).

Bottom-up evaluation starts from data at the level of a single measure. Then it aggregates results from all EEI measures reported by a Member State to assess its total energy savings in a specific field. By contrast to top-down methods, the bottom-up approach provides a direct monitoring of the energy savings resulting from a specific EEI measure. It therefore relies on more disaggregated data (see paper 3176 Vreuls).

In the following, this paper will incorporate the discussion of availability and range of data sources in the transport sector into the bottom-up approach, as it relies on more disaggregated data. The findings aim at serving for both top-down and bottom-up evaluation.

Bottom-up evaluation involves four steps (Thomas et al. 2007). First, the energy savings of one unit (e.g. a person) are calculated. Second, the number of units (e.g. the number of participating persons) is evaluated. The third step considers gross-to-net correction factors (e.g. people who would have switched transport modes anyway). Fourth, the lifetime of the

1. The EMEEES project (Evaluation and Monitoring for the EU Directive on Energy End-use Efficiency and Energy Services) developed evaluation methods with financial support of the European Commission. These can be downloaded at http://www.evaluate-energy-savings.eu. Paper 3,170 provides an overview of the project's overall results.

2. http://www.odyssee-indicators.org

Table 1. Transport-related EEI measures in EU-27

	Vehicle Efficiency		Modal Shifts	
	Taxes on car acquisition/ ownership	Fleet emission limits	Infrastructure improvement (rail, bicycle)	Price incentives for modal switch
Austria	■		■	
Belgium	■		■	■
Bulgaria			■	
Cyprus			■	
Czech R			■	
Denmark				
Estonia		■	■	
Finland		■	■	
France	■		■	
Germany	■		■	■
Greece	■		■	■
Hungary			■	■
Ireland	■	■	■	■
Italy		■		
Latvia	■	■	■	■
Lithuania				
Luxembourg	■			
Malta				■
Netherlands	■		■	
Poland			■	
Portugal				
Romania			■	
Slovakia	■		■	■
Slovenia	■	■	■	■
Spain	■			
Sweden	■		■	■
UK	■	■	■	■

action is set, as only those measures are taken into account, which are still in effect in 2016. Figure 1 illustrates the evaluation steps of the bottom-up approach.

To be as practicable as possible and stimulate continued improvement, a three-level approach is proposed for the harmonised reporting on bottom-up evaluation. The first level is supposed to demand minor evaluation efforts by using conservative EU wide reference or default values, if applicable. The second level shall produce country specific values. The third level aims to maximise the certainty of the quantitative results by using programme-level data and could therefore demand extended evaluation efforts.

Evaluation Conditions and Data Collection

This chapter first introduces the bottom-up formulas to be used and the corresponding data to be collected (see table 2). Thereupon, the different ways to collect this evaluation data are discussed. The discussion distinguishes between vehicle efficiency and modal shifts for each evaluation step. A comparison of advantages and shortcomings leads to recommendations for data collection.

STEP 1: UNITARY GROSS ANNUAL ENERGY SAVINGS

Energy savings are evaluated by comparing baseline consumption with the actual energy consumption. In the transport sector measures might either have an impact on the specific energy consumption of vehicles or their distances covered. The two formulas to derive the unitary gross annual energy savings as given in table 2 reflect this fact.

Vehicle Energy Efficiency

If the EEI measure aims at improving vehicle energy efficiency, it is assumed that without its implementation, a number of consumers would rather buy inefficient vehicles. This requires a definition of what is considered efficient with the help of a baseline. There are two possible ways to establish a baseline.

The first way is to use the European Commission's emission target for the new passenger car fleet in the Community. The Commission proposed to set the target for new cars to 130 g CO_2 per km from 2012 onwards (European Commission 2007). This could be considered a suitable threshold between efficient and inefficient passenger cars and therefore serve as baseline. However, it is unlikely that any consumer changes his/her buying preferences to a considerable extent, i.e. buys a

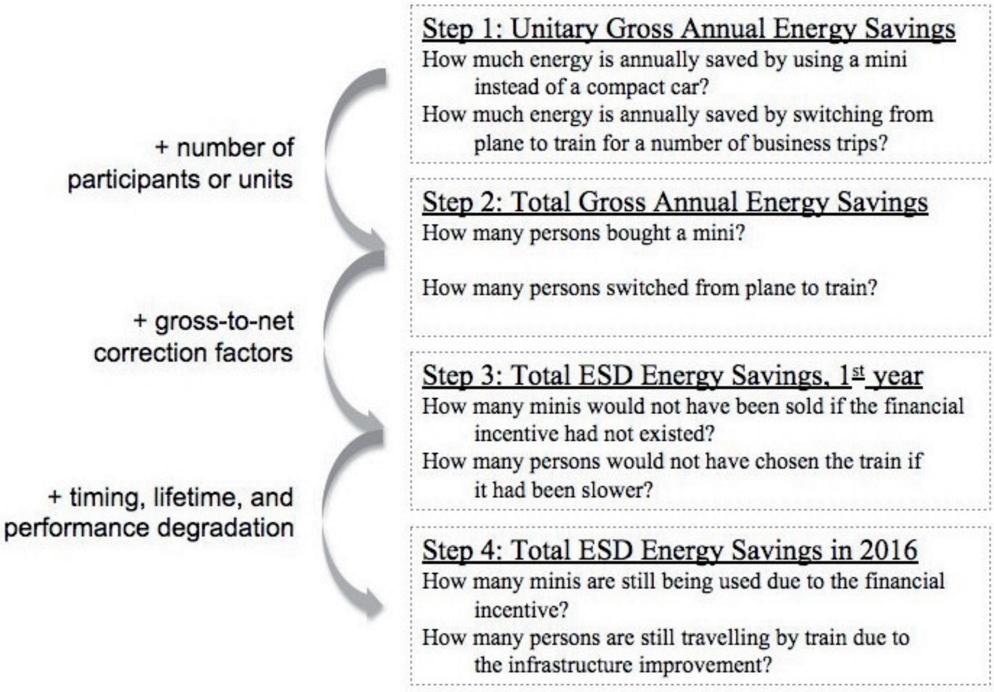

Figure 1. The Bottom-up calculation process.

Table 2. Formulas to evaluate vehicle energy efficiency and modal shifts

		Vehicle Energy Efficiency	Modal Shifts
Step 1	Unitary gross annual energy savings =	$(En_{ineffveh} - En_{effveh}) \bullet ADT$ Unit: Vehicle	$\sum_{i=1}^{N} (ADT_{old\,i} - ADT_{new\,i}) \bullet En_i$ Unit: Person
	With		
	En	Energy consumption of a certain transport mode, • either distinguishing between inefficient and efficient cars, • or accounting for different transport modes "i" (e.g. car, bike).	
	ADT	Annual distance travelled of the unit • "old": before implementation of measure in transport mode i; • "new": after implementation of measure in transport mode i.	
Step 2	Total gross annual energy savings =	Energy Savings from Step 1 • N°	
	With N°	Number of Units	
Step 3	Total ESD annual energy savings =	Energy Savings from Step 2 • (1 – free-rider coefficient + multiplier coefficient) • double counting factor	
Step 4	Lifetime (default values)	100.000 km	2 years

small car rather than a large one, due to a certain EEI measure. Presumably, consumers make their buying decisions in favour of an energy efficient car within the same segment (e.g. a fuel-efficient instead of an inefficient sports utility vehicle). Therefore, the average fuel consumption of all new cars within one segment is the more detailed threshold and a second possible baseline.

However, the energy consumption of the inefficient car the consumer might have bought without the EEI measure's incentive is unknown. To circumvent the problem of comparability, the evaluating body needs to calculate the *average* fuel consumption of all new cars emitting more than 130 g CO_2 per km or the *average* fuel consumption of all cars consuming more than the segment's average.

In both cases, the Member State has to use manufacturer's data as a source of information. Automotive manufacturers specify the specific emissions/fuel consumption of each car within their fleet. These data have to be compared with registration statistics of the different car types in the particular EU Member State.

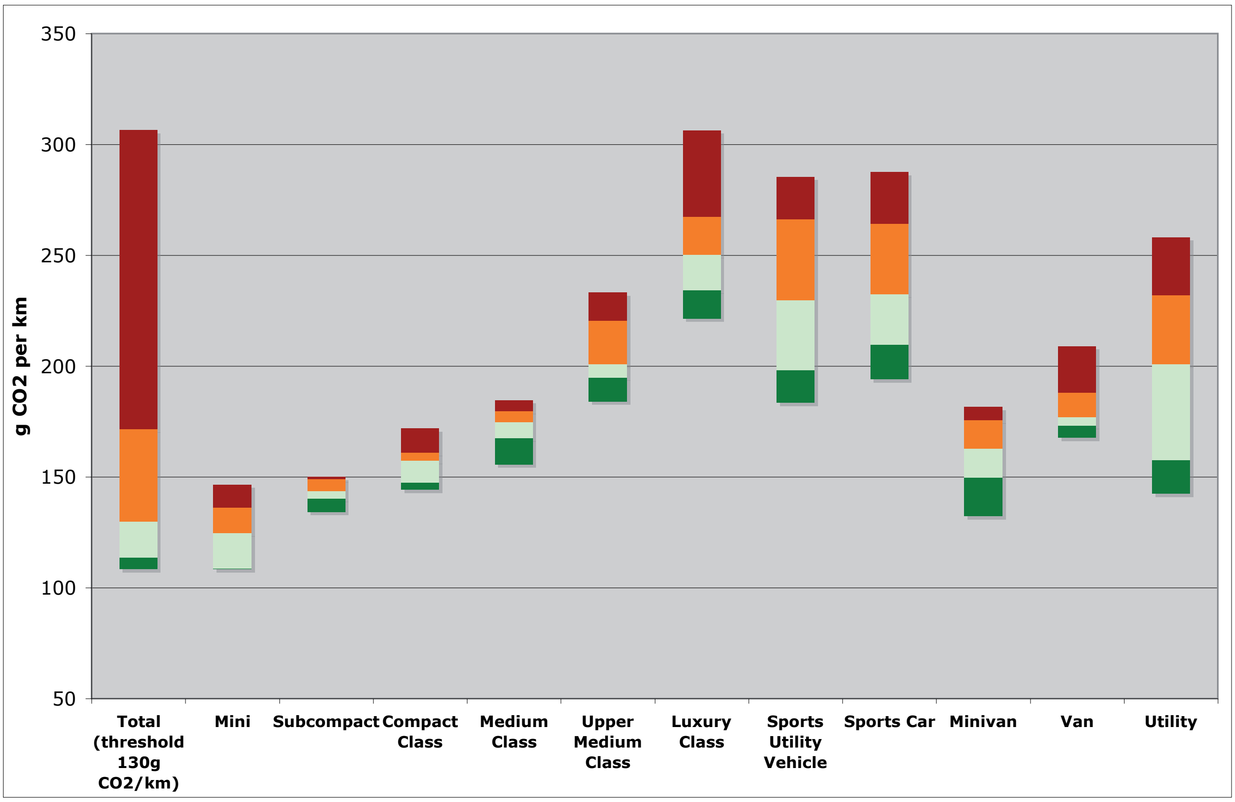

Figure 2. Exemplary analysis.

Figure 2 exemplarily illustrates the analysis for both approaches to establish a baseline. Given is a statistic about car registrations (3.1 million new passenger cars) in Germany in 2007. The statistic distinguishes between car models and their respective CO_2-emissions per km. In every bar the baseline is the border between the light green and the light red area. The borders between the light red and the dark red areas signify the average of inefficient cars, whereas the border between the light green and the dark green areas set the average of energy efficient cars.

In case a person bought a *Peugeot 107* (fuel consumption: 4.6 litres Super per 100 km or 109 g CO_2 per km), then 62.5 g CO_2 per km or 2.6 litres Super per 100 km would be saved, if the baseline of 130 g CO_2 per km is chosen (first way). If the Member State prefers a specific threshold for each segment, then 27.4 g CO_2 per km would be saved (second way).

Subsequently, the particular Member State (e.g. Germany) has to know about the annual distance travelled of the respective car (e.g. a *Peugeot 107*). The formula as given in table 2 demands to gather the *average* annual distance travelled of *all* cars. This is to avoid extensive monitoring, because the average annual distance travelled should be available for each Member State. One way to derive it is via experience-based modelling. Such modelling draws conclusions from fuel sales and registration statistics. Alternatively, regular surveys on mobility behaviour include this as a standard question. The latter approach should deliver more precise numbers.

However, one can assume that in practice the annual distance travelled differs from efficient to inefficient cars. E.g. it can be assumed that rather inefficient vehicles such as luxury cars might more often be used commercially and therefore be used more frequently. On the other hand, drivers might increase their annual distance travelled as a result of the increased mileage of their new and efficient car ("direct rebound effect"). If a Member State wanted to account for potential differences between average annual distances travelled, then it could commission corresponding surveys. As a result, a number of factors that constitute differences between certain car segments could be obtained. Nonetheless it can be assumed, that the different factors either absorb each other or are negligible. Therefore the authors propose to use available data. These should reflect a good picture of reality yet be annually available.

Modal Shifts

The evaluation of modal shifts in passenger transportation proves to be more complex due to more factors to be considered. The Member States have to be aware that their EEI measures might always have an impact on the transport system as a whole. For instance, as illustrated in table 1, most of the Member States have declared infrastructure improvements in their Energy Efficiency Action Plans. As transport is a derived demand, these measures could induce traffic and thus lead to negative savings.

First of all, a Member State should determine which activities are to be considered relevant and in consequence are to be evaluated. For instance, a new railway line might hardly change the mobility behaviour of motorcyclists, whereas a motorway toll might make them consider changing to secondary roads. The evaluation should follow a practical approach and stick to the three levels of harmonisation. If a certain transport mode is only slightly affected, it does not make sense to consider it in level 1 and 2 harmonisation. The exclusion of certain en-

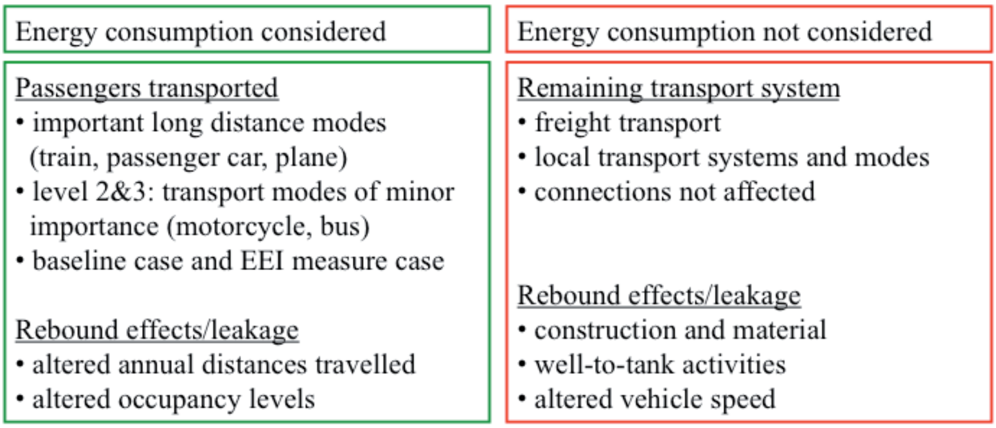

Figure 3. The EEI measure boundary (long distance measures).

ergy efficient transport modes, e.g. a long distance bus, could both provide a conservative approach and reduce evaluation efforts.

In any case, the evaluation does not consider certain leakage emissions. For instance, energy consumption due to construction activities is not accounted for, as the ESD only demands to evaluate changes in end-use efficiency. However, energy savings of local measures might be eaten up by such leakage. Figure 3 illustrates, which activities are to be evaluated, if an EEI measure intends to change modal shares of long distance trips.

The step 1 formula for modal shifts demands to find out the specific energy consumption of the transport modes considered. Here, a direct measurement delivers exact numbers and should at the same time be easy to obtain. For instance, public transport operators regularly publish their energy consumption as expressed in kWh per person and kilometre. However, the usage of different public transport systems could jeopardise the monitoring. Here, normalisation factors serve for comparison. Each source of energy has to be expressed in the same unit and needs to be weighted according to the final energy consumption of an operator/network/area under consideration. In case of any uncertainty, estimations should be kept conservative. E.g. an evaluation remains conservative, if the average kerosene consumption of planes (as the baseline technology in this example) tends to be underestimated or their occupancy levels to be overestimated.

The way to derive the annual distance travelled of a person varies with different circumstances. In Western Europe, people steadily extended their action space as expressed in distances covered per person and year after the Second World War, but action spaces remain more or less stable since the mid-nineties (Schmitz 2001). Among the effects that constitute the changes in the annual distance travelled are:

- energy/transport costs and household budget available,
- working conditions and lifestyles, and
- the number and type of vehicles owned per household.

To factor out such rather mid- to long-term effects and to keep certainty as high as possible, the evaluation should compare the annual distance travelled in the year prior to and after implementation of an EEI measure. Results from regularly conducted surveys on mobility behaviour can serve as appropriate data basis. If the annual distance travelled per person and year tends to stagnate on a national level, a Member State may opt for a wider timeframe without lowering data quality. This could avoid additional surveys.

In case an extra survey has to be avoided and regularly available data quality is poor or not available, there are a number of alternatives to approximate this decisive value. The alternative way to gather data crucially depends on the design of the measure.

If a Member State funds the improvement of a single line railway section, then the annual distance travelled can be evaluated by measuring the connection distance and by estimating the number of annual connections before and after the section's improvement. In order to account for the energy savings of one person, the connection distance has to be divided by the average occupancy level of the respective trains in operation. If a network of lines and services of a local public transport system or of the national long distance railway system is improved, the Member State may figure out both the average single distance covered and the number of annual trips within the network concerned.

However, often only a survey is able to ascertain reliable results for the average distance covered, as it reflects the decision making process of a household and thus the impacts on the whole transport system. Measurements replacing a survey have to be conducted before and after implementation of the particular EEI measure under evaluation. This could make the evaluation cost and time intensive anyway. The Member State will most likely choose the type of evaluation that fits best to the specific measure or package of measures and the available data. In any case, the energy savings calculation should be transparent and the result conservative.

STEP 2: TOTAL GROSS ANNUAL ENERGY SAVINGS

This step demands a calculation of the number of units undertaking an energy saving end-use action.

Vehicle Efficiency

In the case of EEI measures designed to foster efficiency technologies, the end-use action is the purchase of an efficient vehicle (the unit). Motor transport authorities dispose of registration statistics and automotive manufacturers frequently publish sales statistics. Both provide accurate numbers.

Eventually, step 1 and step 2 can be accomplished in one step, as the data basis is similar. The German Motor Transport Authority provides both average emissions and numbers of new cars. Germany simply has to subtract the average emissions of new efficient cars from the average emissions of new inefficient cars (2007: 57.8 g CO_2, see figure 2) and can then multiply this with the number of new efficient cars (2007: 94,619 new cars emitting less than 130 g CO_2 per km). In case the baseline is the average fuel consumption of each segment, the evaluating body has to account for the number of new efficient cars within each segment.

Modal Shifts

Data gathering might be less trivial for measures aiming at fostering modal switches. The unit is one person switching modes of transport. In public transport systems, a sample of passengers has to be counted in a representative way. Afterwards the data sample needs to be weighted according to certain factors such as the number of working days and and the number of connections. If the Member State supports to upgrade bicycle lanes and footpath to improve zero emission mobility, than an occupancy count/estimation of relevant streets and areas would yield good approximations.

Unfortunately, such street occupancy estimations are merely able to consider the effect of certain policies and measures on the traffic flow as a whole. Therefore, it might in the end be easiest to conduct a household survey before and after implementation of the EEI measure, that accounts for all transport modes and the particular area under consideration (e.g. a city).

STEP 3: TOTAL ESD ANNUAL ENERGY SAVINGS

In order to obtain the energy savings that can be assigned to the particular EEI measure under evaluation, three different correction factors have to be considered. The quantification of:

- the free-rider effect and
- the multiplier effect

answers the question: "What would have happened, if the EEI measure had not been introduced?". Moreover, the "double counting factor" accounts for packages of measures that all aim at fostering the same end-use action. E.g. both a vehicle labelling scheme and a carbon-graduated vehicle circulation tax aim at fostering the purchase of efficient passenger cars. The energy savings induced must only be counted once.

The free-rider effect is not explicitly mentioned in the ESD, but including energy savings achieved by free riders in the total ESD annual energy savings would mean to include a part of the autonomous energy efficiency improvements. Therefore, it should be considered if the aim is to evaluate additional energy savings due to EEI measures.

Vehicle Efficiency

The Member State can decide to conduct a survey. To obtain both the free-rider effect and the double counting factor, the survey could figure out the reasons for the purchase of a car and thereby explicitly mention all EEI measures under evaluation. E.g. a survey should determine if and to what degree a person considered vehicle labelling and a carbon tax decisive for the decision to purchase an efficient car. In order to determine the multiplier effect, the survey could determine, if the labelling system had been the starting point for any other end-use efficiency action.

Alternatively, the Member State could monitor the market shares of efficient vehicles during the five years prior to the implementation of the EEI measure under evaluation. An abrupt change of a previously constant development would indicate its impact. For instance, the market share of new cars emitting less than 130 g CO_2 per km in Germany in 2007 was 3.02% (own calculation, data source: German Motor Transport Authority 2008). Germany could conduct this analysis in the five years before the implementation of its vehicle circulation tax reform. The 5 year development could be linearly extrapolated and the extrapolation be considered the free-rider effect. This alternative would be a top-down approach to accomplish step 3.

Modal Shifts

Mode switches are the result of several interdependent as well as independent factors. E.g. the "Theory of Planned Behaviour" (Ajzen 1991) explains that social pressure is an important factor to take action or to refrain from taking action. According to this theory, the probability to use public transport increases, if the individual feels a social pressure to using public transport. Considering the individual decision making process, it might prove to be difficult to definitely assign modal shifts as evaluated in the first two steps to certain EEI measures.

Price elasticities are an economic approach to evaluate the impact of a certain measure or package of measures. The IEA has conducted such an analysis for a number of local transport measures, but it remains unclear how elasticity assumptions were derived (IEA 2005). Alternatively, a Member State could check if the implementation of its measure and the increase of the oil price are overlapping. If this is hardly or not at all the case, the free-rider effect could be considered negligible.

A representative household survey most likely is the most appropriate way to derive all gross-to-net correction factors. In the scope of a survey, the impact of a particular measure on the decision making process of an individual could explicitly be asked for.

Another, less expensive way to deal with the gross-to-net correction factors could be to assume the free-rider effect and the multiplier effect to neutralise each other. Given the costs of surveys, it appears advisable to only evaluate both effects for EEI measures with total gross annual energy savings above 50 million kWh or 5% of a Member State's target. To account for the double counting factor, a Member State could evaluate the combined effect of packages of similar measures.

STEP 4: ENERGY SAVING LIFETIME

The European Commission decided to assign a certain lifetime to every EEI measure. After the expiration of this lifetime, the energy savings effect of the respective measure is considered zero. Only the annual energy savings achieved and still existing in 2016 are accounted for the final ESD target.

Table 3. Assessment of evaluation effort and certainty

Value required	Type of evaluation	Effort	Certainty
Energy consumption of efficient and inefficient cars	Analysis of registration statistics and manufacturers' data	medium	high
	Survey	high	high
Average energy consumption of cars	Top-down indicators	low	high
Energy consumption of planes and trains	Direct measurement	medium	high
	Top-down indicators	low	medium
Occupancy levels of planes and trains	Operators' statistics	medium	medium
Occupancy levels of cars	Top-down indicators	medium	medium
	Survey/literature	high	high
Annual distance travelled of efficient cars	Top-down indicators	low	medium
	Survey/literature	medium	high
Annual distance travelled of persons	Survey	high	high
	Own assumptions	low	medium
Number of cars	Registration statistics	low	high
Number of persons (passengers etc.)	Survey	high	high
	Passenger counts	medium	medium
Free rider coefficient Multiplier coefficient Double counting factor	Survey	high	high
	Own analysis	medium	medium
	Own assumption	low	low

Vehicle Efficiency

The European Commission has charged the European Committee for Standardization (CEN) to proposed default energy saving lifetimes for all kinds of technologies. This expert committee has set the lifetime of vehicle engines at 100,000 km (CEN 2007). This (conservative) lifetime has to be divided by the average annual distance travelled of the unit (one vehicle) as identified in step 1. National values about average lifetimes of all kinds of vehicles should be available as well and can be used instead of the CEN value.

Modal Shifts

The CEN has proposed the default saving lifetime for all EEI measures aiming at behavioural changes to be two years. Modal shifts are stipulated behavioural changes. This appears to be a very short time horizon, as measures would have to be implemented in 2014 earliest, in order that they were countable towards the final ESD target. The rationale behind this is to keep conservative and to encourage additional evaluation efforts. Hence, the authors propose to conduct a survey after two years of implementation to assess the continuation of the energy savings. Such a survey could be conducted after every two years, and new lifetimes could be set for the resulting energy savings. Whereas the effect of a behavioural soft measure might indeed decline and disappear early, a new rail or metro line most likely has a long-lasting effect.

If Member States set new lifetimes, which are longer than two years, then they should take technology improvement into account. This can be done either by annually validating the specific energy consumption of all vehicle categories to be monitored or by assuming a certain technology change factor. A reasonable default technology improvement factor for cars and buses is 0.99, i.e. to assume fuel consumption to decline by 1% per year (CDM Executive Board 2006).

Conclusions

The capability to evaluate energy savings is crucial. It does not only support the implementation of the EU Directive on Energy End-use Efficiency and Energy Services (ESD), but it generally helps decision makers in elaborating and justifying policies and measures for mitigating climate change and reducing non-renewable fuel consumption.

The trade-off between evaluation costs and the level of (un-) certainty is an obvious part of each step within the bottom-up approach. Energy efficiency improvement (EEI) measures fostering vehicle efficiency demand less evaluation efforts than those fostering modal shifts. This is due to two reasons. First, less data has to be collected and second, the collection itself is less comprehensive. The evaluation of measures fostering modal shifts has to consider effects on the transport system and traffic flow as a whole.

Therefore, often a survey seems indispensable to guarantee valid quantitative results. On the other hand, the evaluation should be facilitated without high transaction costs. One way to resolve this dilemma could be to collect evaluation experiences for reuse. This would allow the evaluating body to take over results from similar measures. The obligation to monitor and evaluate EEI measures within the ESD implementation could be the starting point to gain comprehensive experience. However, this demands more research on the conditions under which evaluation results can be transferred from one situation to another.

Table 3 summarises the findings of the paper in more detail. In its first column, it lists all values to be gathered to evaluate vehicle efficiency and modal shift EEI measures. In the second column, it specifies the possible ways to collect the corresponding data. In the following two columns, it illustrates the trade-off between evaluation expenses and certainty of findings.

References

Ajzen, Icek: The theory of planned behavior. In: Organizational Behavior and Human Decision Processes, 50, 179-211, 1991.

Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services

CDM Executive Board: Approved baseline methodology AM0031. "Baseline Methodology for Bus Rapid Transit Projects". Bonn, 2006

CEN (European Committee for Standardization): Saving lifetimes of Energy Efficiency Improvement Measures in bottom-up calculations. Final CWA draft (CEN WS 27). Brussels, 2007

EEA (European Environmental Agency): Climate for a transport change. TERM 2007: indicators tracking transport and environment in the European Union. Copenhagen, 2008

European Commission: Keep Europe moving. Sustainable mobility for our continent. Mid-term review of the European Commission's 2001 transport White Paper. Luxembourg, 2006

European Commission: COM(2007) 19 final, 2007

German Motor Transport Authority (Kraftfahrtbundesamt): Fahrzeugzulassungen. Neuzulassungen. Emissionen, Kraftstoffe. Jahr 2007. Flensburg, 2008

IEA (International Energy Agency): Saving Oil in a Hurry. Paris, 2005

Thomas, Stefan; Nilsson, Lars J.; Eichhammer, Wolfgang; Vreuls, Harry; Broc, Jean-Sébastien: How much energy saving is 1% per year?, ECEEE 2007 Summer Study – Saving energy – just do it!, conference proceedings, 4-9 June 2007, volume 2, panel 4, panel 5, La Colle sur Loup, France, 2007

Schmitz, Stefan: Revolutionen der Erreichbarkeit. Gesellschaft, Raum und Verkehr im Wandel. Opladen, 2001

SRU (German Advisory Council on the Environment, Sachverständigenrat für Umweltfragen): Umwelt und Straßenverkehr. Hohe Mobilität – Umweltverträglicher Verkehr. Berlin, 2005

Acknowledgements

The authors wish to thank all partners of the EMEEES project for their contributions to the results presented here. In particular, the authors would like to thank Stefan Thomas (Wuppertal Institute) for his comments and suggestions.