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# ASSESSMENT OF TRANSPORT POLICIES TOWARD FUTURE EMISSION TARGETS

## A BACKCASTING APPROACH FOR STOCKHOLM 2030

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Stockholm has set a target for greenhouse gas emissions in the year 2030, based on the United Nation's (IPCC) recommendations for an acceptable $CO_2$ level in the atmosphere. In this study we use a backcasting framework to analyze a range of specific transport policies and fuel technology related developments with respect to the emission target. Our study employs a transport modelling system, traditionally used for forecasts, to quantify the impacts of various travel demand measures (TDM). Our study shows that the change in travel demand, induced by various travel policies, will not suffice on its own to reach the target. Even if fuel price is tripled, a substantial share of renewable fuels is required for target achievement. While our study shows that travel demand measures have a fairly small effect on $CO_2$ emissions, it also hints at other compelling reasons for introducing such measures. Constructive strategies for the transport system would not only contribute to reduce risks with climate change. Even small reductions of transport volumes might imply large socio economic savings in traffic related costs, reduced emissions of substances with health impacts, fewer accidents, shorter travel times and higher travel time reliability. These aspects are arguably all part of a sustainable transport development.

*Keywords*: Mobility management; travel demand management; $CO_2$ emission target; policy appraisal; backcasting.

## Introduction

Finding strategies for sustainability is of global concern, with climate change and environmental deterioration as prime examples. In this context, Stockholm has set a target of reducing greenhouse gas emissions by about 70% until 2030 (Stockholm Action Programme, 2003). In this study, we focus on the transport sector and the central question we pose is: how effective are various types of travel demand measures (TDM) and mobility management services in reaching future global targets on greenhouse gas emissions? To answer this question properly for the year 2030, where large uncertainties regarding e.g. fuel prices and technological development exist, we use the transport demand model SAMPERS (Johansson, 2001; Beser and Algers, 2001) and the transport assignment model EMME/2,[1] by which we experiment on three alternative types of policy measures contributing to achieving the emission target:

(i) Reduced transport volumes from future adoption of alternative, less car dependent "mobility management services", e.g. car-sharing, ride-matching, telecommuting, videoconferencing, cycling and public transport.
(ii) Specific travel demand measures such as traffic tolls, car-free streets, increased fuel taxes, and free fare public transport.
(iii) Increased share of renewable fuel vehicles and fuel efficiency regulations on private vehicles in the transport system.

The difference between mobility management services and other TDMs used in this study is that the former represent alternative means of communication is not yet implemented at a large scale in the transport system. These might well be part of a more sustainable future transport system and should therefore not be kept out of the discussion. However, to what extent is not straight forward to assess. Thus, reduction of transport volumes due to mobility management services is therefore modelled as macro level reduction of travel demand in the model framework since it involves more or less extensive assumptions. We base our assumptions regarding future adoption rates of mobility management services on (a) research literature covering the subject and (b) a stated preference survey conducted in a business district outside Stockholm, testing the attitudes to company travel and meeting policies, aiming at reducing staff travel costs and emissions by implementation of mobility management services (Robèrt, 2003).

In this study we treat renewable fuels as carbon-neutral, i.e. from a lifecycle perspective; use of renewable fuels does not imply a net contribution to the greenhouse effect. Furthermore, differences between different renewable fuels in terms

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[1] Information available from INRO, http://www.inro.ca.

of their CO2-reducing potential, emissions involved in the production and transport process, and other environmental, social and economic impacts are not reviewed in this study.

Besides contribution to global warming, reducing local pollutants, accidents, and congestion are also legitimate objectives for a sustainable transport system (WSSD, 2002, §21). Some results regarding these local objectives are discussed, but a thorough investigation of them is outside the scope of this study. We have further assumed that the transport system will have to pull its own weight, and reduce emissions to the same extent as other sectors, which makes these results relevant for other similar cities as well, i.e. we do not involve site-specific assumptions concerning other energy and emission sources in Stockholm, such as heating and electricity.

To concretize the emission target for 2030 and how to reach this state in the future from the situation of today, we use a backcasting approach (Robinson, 1982), where forecasting is applied to derive concrete states and paths in the backcasting framework. Forecasting and backcasting are different approaches in the context of analysing future outcomes in complex systems. Forecasting on the one hand means to make statements regarding the future based on explicit or implicit assumptions from the present situation and model how changes affect future development. Backcasting on the other hand is a strategic problem-solving framework, searching the answer of *how to reach* specified outcomes in the future. The idea of synthesising forecasting into a backcasting framework is developed in other studies, For references see (Robert, 2003; Höjer 1998; and Höjer and Mattsson 2000).

The EU project PROSPECTS (May *et al.*, 2003) was geared towards helping cities with planning guidelines to tackle the issue of sustainability. One of the main points from PROSPECTS is that careful use of an appraisal framework is an essential part of the planning process (Minken *et al.*, 2003). Planning styles may vary, but it is nonetheless always necessary to assess differences in effectiveness between alternative policy solutions (Plaut, 1998).

While our focus in this study is the impact on $CO_2$ emissions, we will also include some estimates of costs and benefits of other related effects from the changes introduced, to facilitate comparison to other policies, e.g. new infrastructure investment. We are not, however, attempting to do full cost-benefit analyses (CBA) of the policies. It should also be noted that CBA may be useful, and is often required when considering infrastructure investment, but that does not preclude doing more multi-dimensional assessments, in the form of e.g. multi-criteria analysis when it is necessary to highlight conflicting objectives (Minken *et al.*, 2003; Martinez-Alier *et al.*, 1998).

In the evaluation of different paths derived in this study, we consider emission costs and accident costs coupled to the traffic flows. Litman (2004) points out the

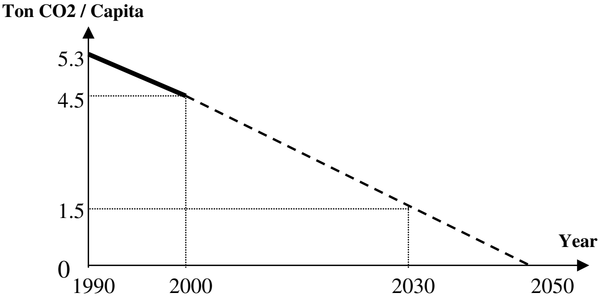

Fig. 1. Graphic construction of the target for Stockholm's action programme against greenhouse gas emissions (2003). The Stockholm municipality's emission target for 2030 and 2050 is based on an extrapolation of the $CO_2$ reduction rate between 1990 and 2000.

necessity of including traffic safety and health aspects when evaluating various TDM and mobility management services. In this study we will assume a direct relationship between transport volumes and accident costs (Lindberg, 2005). According to Litman (2004), each percentage of mileage reduction in the transport network might imply even a relatively larger saving in crash-costs since often more than one vehicle is involved in traffic accidents.

Stockholm reached the target of not increasing the level of greenhouse gas emissions from the year of 1990 (5.3 ton/capita) to the year 2000 (4.5 ton/capita). During this time, transport volumes have continued to increase and the reduction target between 1990 and 2000 was met primarily on account of introduction of district heating plants and use of renewable fuels in the public transport system. The intention is now to continue this positive development toward the United Nations (IPCC) recommendations for stabilizing the level of $CO_2$ in the atmosphere to an "acceptable risk level" of 450 ppm (Stockholm action programme, 2003). This long-term recommendation would be achieved by reducing emissions of greenhouse gases to 1.5 ton per capita per year (Stockholm action programme, 2003). This would mean that the Stockholm inhabitants would have to reduce present levels of greenhouse gas emissions by about 70% on average. This level of greenhouse gas emissions should be reached about the year of 2030 if extrapolating the emission reduction development between the levels of 1990 and 2000. The vision is to continue this reduction rate till the year of 2050 — a situation when Stockholm would have got rid of all use of fossil fuels, i.e. an extrapolation of the reduction rate between 1990 and 2000 would result in zero emissions at the year of 2050 (see Fig. 1 above).

In Sec. 2 the conceptual, backcasting influenced appraisal framework applied for this study is presented. In Sec. 3, we present the results from the different types of target-oriented changes, consistent with target achievement 2030. Finally, a discussion and the conclusions make up Secs. 4 and 5 respectively.

## Development of the Framework

By what method should the components of the transport system be analyzed in order to find feasible ways to a more sustainable development? One approach would simply be to forecast the emission reductions from e.g. new mobility services, based on market demand and present conditions, extrapolate the results and (most likely) find that the predictions do not match the $CO_2$ target for Stockholm 2030. The question of how the $CO_2$ target might be achieved would then not be fully explored, since this only gives us the gap between the desired target and the expected development. Consequently, we have not touched upon the issue of what processes or measures that could bring the two situations closer. A more problem-oriented approach for seeking the answer to our question would be to analyze the situation from a backcasting perspective.

The term "backcasting" refers to a planning approach that departs from a vision of future success, followed by looking back and seeking strategies or "feasible paths" to get there by. According to Dreborg (1996), backcasting is particularly useful when:

- The problem studied is complex, affecting many sectors and levels of society;
- There is a need for a major change;
- Dominant trends are part of the problem;
- One of the reasons for the problem is externalities, i.e. problems that the market does not treat properly; and
- The time perspective is long enough to allow for deliberate choices.

When developing backcasting paths toward the emission target of the transport system in Stockholm 2030, the idea is to make decision makers iteratively sort out the most effective set of strategies in order to reach target fulfilment. How should the new mobility services, together with other TDM be implemented in reality according to factors such as economic feasibility, present traffic situation, public opinion, etc? By modelling the transport system at large, pitfalls such as unexpected rebound effects and sub optimizations could be avoided.

In our framework we have three state descriptions (A, B and C) in the backcasting framework (Fig. 2). Incorporating the target achievement (state description C) in the framework makes it possible to "count backwards" how to reach this state from the present situation (state description A). In state description C the ultimate requirements on the transport system are modelled in relation to the "do-minimum

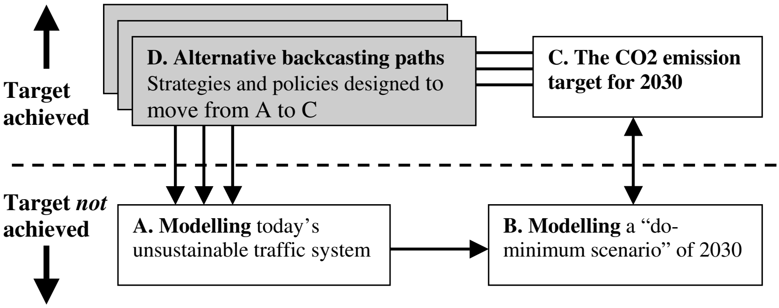

Fig. 2. A structural backcasting framework. The state descriptions (A–C) and the backcasting paths (D) are treated separately in order to avoid aggregation of the analysis.

scenario" (B). The alternative backcasting paths (D) represent various practical solutions, bridging the gap between the two state descriptions A and C.

***State description A:*** Initially we investigate specific key parameters of the unsustainable transport system of today, such as e.g. absolute transport volumes, share of private car, public transport and goods transport, present greenhouse gas emission levels, fuel prices, $CO_2$ taxes, in vehicle time costs, emission costs and accident costs generated in the transport system.

***State description B:*** Here we carry out a traditional "do-minimum-forecast" of the traffic situation at the year 2030 if no specific target-oriented actions are taken. We incorporate socio economic aspects like predicted population growth, socio economic growth, expected modifications to the road network and more efficient fuel combustion standards.

***State description C:*** The emission target is to reach a $CO_2$ level of 1.5 tons per capita (Stockholm Action Programme, 2003). For Stockholm this would correspond to about a 70% reduction of present greenhouse gas emissions per capita. Using state description B as a reference point, we model the emission quantities needed to reach target fulfilment. To arrive at state description C, *above* the threshold line in Fig. 2, $CO_2$ emissions from the transport system must reach 0.35 ton/capita.

The three state descriptions presented in Fig. 2 constitute solid platforms in the backcasting framework. Each state is characterised by a range of *indicators*, describing the key elements of the planning objectives (e.g. transport volumes, emissions and socio economic costs). Obviously, the emission target is necessary, whereas other indicators may be used to produce a richer picture of the alternative future states. The idea of modelling these state descriptions is to, as far as possible, "quantify what is quantifiable" with the intention of assessing the impact from each policy measure.

***The backcasting paths D:*** The backcasting paths in Fig. 2 consist of concrete measures or strategies, consistent with the requirements for target achievement in state description C. When forming the backcasting paths we experiment with the assumptions regarding changes to state description B. The forecasting model is employed to assess the impact from the various policy measures implemented.

Since consequences and effects from integrating new mobility services into the transport system are hard to assess, some of the backcasting paths include assumed levels of reduced transport volumes based on assumptions of future use rates of less car dependent means of communication. Even though the evaluation of hypothetical levels of mobility management services is less strict and quantitatively exact (than the effect from specific TDM such as e.g. traffic tolls and increased fuel prices), it provides guidance on hypothetical advantages linked to integration of mobility management services into the transport system. This, in turn, could stimulate initiatives to develop and integrate these alternatives as part of a sustainable transport system. The backcasting approach enables a decoupling of the state descriptions on the one hand, and the analysis of different alternative backcasting paths on the other.

The rationale for decoupling the analysis of the state descriptions and the feasible paths in the backcasting framework (see Fig. 2) is consistent with Robèrt (2003), using forecasting in order to select strategies for sustainable development. In state description C we set the ultimate principles for the desired level of transport related greenhouse gases, according to e.g. absolute transport volumes and proportion of renewable fuel vehicles in Stockholm 2030. By what means the mobility services and TDM could meet these conditions (selection of backcasting paths) corresponds to the derivation of the most efficient tools and how to best coordinate them for target fulfilment.

There are three prominent motives for developing a backcasting-influenced framework in this study: Firstly, it reduces the level of complexity in the problem formulation. The strict derivation of the specific state descriptions on the one hand, is kept separate from the experimentation of feasible backcasting paths on the other. This increases the stability to the total framework, by letting the state descriptions serve as “solid ground” or “stable reference points”, between which trialling of the more uncertain backcasting paths can be conducted. Secondly, stakeholders (here, Stockholm municipality) can assess the effectiveness of different measures in relation to each other and sort out the most economically, socially and politically efficient path fulfilling the requirements for target achievement. In addition, there might be consequences on other aspects than $CO_2$ emissions, such as accidents or in vehicle time. Thirdly, if it is hard to determine the exact effect from mobility management services and TDM in practice, we can analyze the *relative* importance of the different measures, i.e. settle what changes posed on the transport system has the *greatest* impact on target achievement, and what changes are of minor importance. From that information, decision makers could assess what practical measures leading to state description C should be prioritized over the other.

Banister *et al.* (2000) develop predefined images of a sustainable future transport system and construct feasible backcasting paths consisting of different proportions of technological expectations and decoupling of transport volumes and GDP. Like Banister *et al.* (2000), we create a *set* of alternative backcasting paths, all in principle consistent with the long-term target but where none is prioritized to the other in advance. By defining principles for "success" in the system rather than scenarios, (in our case a predefined emission target for the traffic system of Stockholm), concrete strategies and actions toward target achievement (here concrete traffic policies) are allowed more flexibility than if using fixed images (Ny *et al.*, 2005) (Robèrt, 2000). Ny *et al.* and Robèrt compare this way of planning with chess, where it is principles for checkmate that guide the game, not a specific scenario regarding the positioning of the pieces. This may be advisable since it allows decision makers and stakeholders to plan and invest strategically without requiring very detailed assumptions about the distant future. Priority is given to such early investments that can (i) tackle existing circumstances (e.g. budget constraints, economic payback, public opinion, political climate, etc.) *as well as* (ii) serve as flexible platforms for various investment paths towards compliance with the principled goal.

The framework is developed to assess the effectiveness of various policy measures, aiming at reaching the target level of $CO_2$ emissions. First, it is worth pointing out that this study does not intend to fully explore the political feasibility or economic efficiency of the policies, since we are mainly interested in different policies' leverage with respect to the $CO_2$ target. Second, a natural extension to the present study would be to test various combinations of policy measures. However, introducing combinations increases the number of possible paths quickly. If we were to test all combinations of the tested travel demand measures (Tables 8–11 in Appendix) we would end up with 128 combinations, assuming four levels (base level plus three adjusted) for both fuel price and fuel efficiency. For each of these 16 combinations, the three remaining TDM could be either present or not, yielding a total of $16 \cdot 2 \cdot 2 \cdot 2 = 128$ combinations.

Presenting them in tabular form would not be useful, so it would become necessary to form some kind of ranking system. It is usually done by assigning weights to each indicator and then summing them up in an objective function (Minken *et al.*, 2003; Jonsson, 2003). We would like to stress that the intention, when formulating an objective function, is not primarily to let the appraisal framework find the optimal solution, but to aid decision makers in their processing of large amounts of information. Consequently, such objective functions must be formulated with care, within a larger planning process, with involvement from decision makers and stakeholders.

## Strategies for Stockholm

The transport model SAMPERS is used to study how different policy measures can be used to get from today's situation (state description A), to a desired future (state description C). The SAMPERS and EMME/2 combination used throughout this study is well suited for the kind of assessment we do. It is in fairly wide use in the Stockholm region, and especially the EMME/2 networks have been for a long time, which reduces the risk of errors, and adds to the confidence that the models produce reasonable results. The demand models in SAMPERS, incorporates state-of-the-art random utility models for trip generation, destination and mode choice, where trip chaining is also taken into account. EMME/2 is used for assigning transport demand to road and public transport network. The link flows then forms the base for the effect calculations described in the appendix.

The impact of policy measures on future behaviour is thus fairly complex. It is, for instance, evident in the result that there is a diminishing return in terms of $CO_2$ emission reduction from increasing the fuel price. There are nonlinearities introduced both from the demand models themselves, and from the network assignment procedures, where the travel times depend nonlinearly on flow. Furthermore, the nonlinearities of the model also imply that assessing the impact of combinations of policies is not only a matter of adding up impacts from the tests of single policy measures.

The measures we study directly through SAMPERS fall into the following two categories:

*Travel demand measures (TDM)* include such things as:

- Increased fuel prices or mileage-based user charges, e.g. mileage based insurance systems (DeCorla-Souza and Whitehead, 2003; Hayashi, 2001)
- Free fare public transport
- Traffic tolls
- Car-free streets in the city centre

The second group of measures is centred on *fuel technology*, in particular:

- The effect of a certain share of renewable fuels in private vehicles in Stockholm.
- Regulation on fuel-efficient vehicles (i.e. smart cars) in Stockholm, including the potential rebound effect from more efficient fuel consumption in vehicles. Here we derive the net effect from reduced emissions per vehicle in relation to a potential increase in vehicle use (from reduced fuel price/km).

Increased share of renewable fuel vehicles will play a central role in the formulation of feasible backcasting paths. With a sufficiently high renewable fuel mix in the transport system the target will always be reached. Thus, the renewable fuel mix required in each backcasting path, serves as an effectiveness measure of the other policies included in each specific backcasting path. The lower the required renewable fuel mix, the more effective is the specific policy measure tested. Most backcasting paths derived in this study include a renewable fuel mix of about 50–60% — a mix that we assume reasonable for 2030 (Droege, 2002), (Urry, 2004), (Campbell and Laherrere, 1998). To make the emission target for 2030 sensible, we assume that the public transport system is entirely renewable fuel driven. Buses are assumed to be using fuel cell technology, and the electricity to rail traffic is produced from renewable sources of energy — a process that has already been set in motion in Stockholm.

It is not straightforward to quantify the exact adoption rate or effect from various combinations of mobility management services in the future. Instead we estimate the effect from specific *assumptions* regarding these services. Effects associated with increased future adoption of new mobility management alternatives are assessed indirectly. The intention is to give a qualitative argument on the potential impact a mobility management service can have on some key indicators of the system. We have experimented with four different potential impacts:

- The aggregate emission reduction from an X% reduction of total private vehicle trips in Stockholm, calculated on vehicle and emission standards in the transport system of 2030.
- The emission impact from reducing the number of work commute trips and local business trips by X%.
- The emission effects from an X% reduced car ownership in Stockholm.
- Local effects from reducing commuting volumes by X% between Stockholm and the largest telecom business district in Sweden (Kista), caused by an assumed successful implementation of company travel plans in the area (e.g. telecommuting programs at companies etc). In relation to this, we will give a quantitative measure of the potential rebound effects caused by reduced travel times in the transport network.

Different levels of X are tested to explore the possible range of impacts from mobility management services.

In summary, we have developed a target-oriented framework, geared to assess the effectiveness of alternative policy measures (mobility management services and travel demand measures), on condition that Stockholm's target for greenhouse gas emissions is achieved. The results are presented in the next section. Bear in mind that the analysis would have to be enhanced with cost estimates and a more detailed view of where costs and benefits go, in order to answer questions on political or economic feasibility.

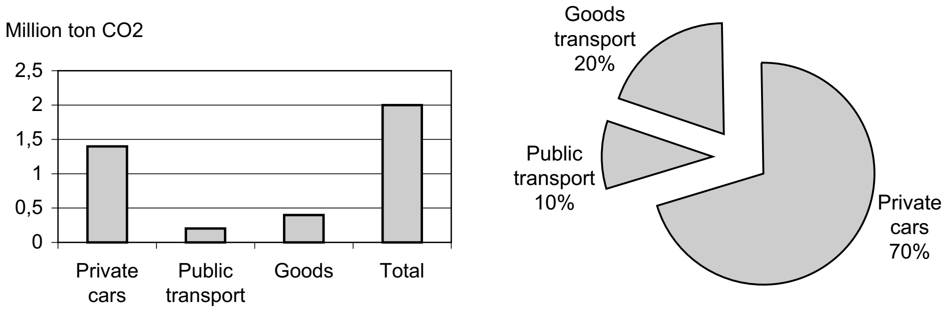

Fig. 3. State description A: The modelled emission level of today, and their distribution over three transport sectors.

## Results

We use the transport demand model SAMPERS (for technical details see SIKA, 2001) to generate the demand for each policy setting. The travel demand is assigned to a network with EMME/2. The effects from the transport system in terms of emissions and accidents are based on the flow, the vehicle speed, and the vehicle type, on each individual road link. The effect model is presented in the Appendix. This chapter presents the findings from the modelling work.

### The present situation (State description A)

Figure 3 presents the proportions of $CO_2$ equivalents in Stockholm County at the present situation (state description A). Evidently, private car transport corresponds to 70% of the slightly more than 2 million tons $CO_2$ equivalents emitted from the transport system of Stockholm per year.

$CO_2$ equivalents from the public transport system are 0.2 million tons at present. This figure will be eliminated in all 2030 scenarios where we assume a renewable fuel driven public transport system. A 70% $CO_2$ reduction per capita corresponds to a $CO_2$ equivalent level of 0.35 tons per capita (Table 1 in the Appendix).

### "Do-minimum" scenario of 2030 (State description B)

Figure 4 presents the proportions of $CO_2$ equivalents in the do-minimum scenario of 2030 (state description B). This is a prediction of the $CO_2$ equivalent level at 2030 if disregarding the emission target. In this scenario we assume that the public transport system is entirely renewable fuel driven.

In state description B, private car kilometres and adherent accident costs has increased with 28% in comparison to state description A. This transport increase is mainly due to the fact that we assume an economic growth of 2% per year (implying

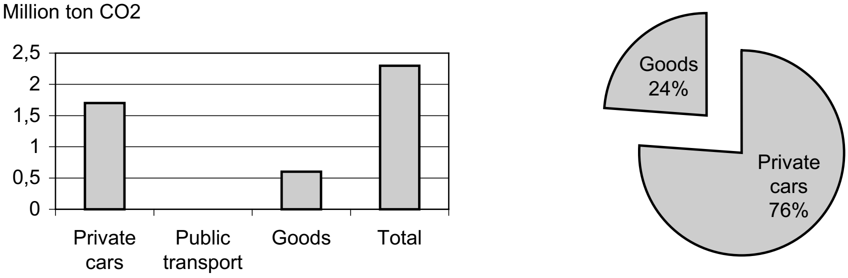

Fig. 4. The annual emission level in a "do-minimum scenario" for 2030. The public transport system is assumed using renewable fuels exclusively.

e.g. increased car ownership) and a population increase from 1.8 million today to 2.4 million until 2030 (Carle, 2000). Nevertheless, the $CO_2$–equivalent level is just 7% higher in 2030 than today because of the drastic renewable fuel assumption of the public transport system. In addition, we have assumed more effective combustion and emission standards in future vehicles, implying that emissions per unit of fuel are assumed to be lower in the 2030 prediction (Biding and Lindqvist, 2005). Also, because of the population increase, the per capita measure is lower in 2030 than today. However, the $CO_2$–equivalent level must be reduced by 63%, from 2.27 to 0.84 million tons per year, to attain the emission target of 0.35 tons per capita (Table 2 in Appendix).

## Backcasting paths to target achievement

Each of the feasible paths to the desired target of greenhouse gas emissions at the year 2030 (given in state description C, see Tables 3–11 in Appendix), incorporates a certain level of renewable fuel in order to reach the target of 0.35 ton $CO_2$ equivalents per capita. The renewable fuel mix can be viewed as picking up the remaining slack between the effects of a policy, and the target level of $CO_2$. We have chosen the levels of the policy variables with consideration to the following two criteria: (a) the measures are meant to be pushing the envelope, but still be reasonable, from a political point of view, and (b) we aim at a renewable fuel mix close to 50% since we assume this is a fair assumption for technical feasibility of renewable fuel technology at the year of 2030.

### *Implementation of new alternatives*

Future adoption of more resource efficient alternatives to private car (i.e. mobility management services) is to a great extent dependent on factors such as local company travel plans, integration with the public transport system, fuel prices after peak-oil, and specific TDM enforced by the Stockholm municipality and the road administration. We experiment with changes to the transport system associated with different adoption rates of mobility management alternatives and estimate the aggregate $CO_2$ reduction from reducing 10%, 20%, 30% of (a) all private car trips, (b) only commute- and local business trips. Reducing car-ownership by 10% and 20% is also investigated. The difference in magnitude between (a) and (b) are small, revealing that work commute and local business trips (i.e. work related travel) are the far most important travel categories with private car. The impact from reducing car-ownership follows almost exactly the same pattern as reducing work-related travel. Still a renewable fuel mix in the range 51% to 61% is needed in these backcasting paths in order to reach target fulfilment of greenhouse gas emissions.

Although we do not attempt to explore the costs and benefits fully in this study, some numbers on the potential savings are illustrative. For example, reducing private vehicle kilometres only to a marginal extent implied significant savings in accident costs and emission costs. Reducing all private vehicle trips by 10% corresponds to 750 million SEK (1 Euro = 9.35 SEK[2]) savings of accident costs and 360 million SEK savings of emission costs, implying a total annual socioeconomic saving of 1.11 billion SEK. The corresponding figure from reducing work commute and local business trips only is 760 million in total. Only the most radical reduction level (30% of all private vehicle trips) would come close to the aim of a 50% share of renewable fuel mix. This would correspond to a total saving of accident and emission costs of 3.25 billion SEK, a figure that is probably out of reach to achieve in reality but which shows the economic potential of reducing transport volumes.

In addition to savings in emission and accident costs, one could expect potential savings from road users' reductions in total in vehicle time costs. However, it is not straightforward to give a fair estimate of in-vehicle time savings from reduced transport volumes since we do not have information of how the time savings are used. Nevertheless, just to give a hint of the potential savings associated with reduced transport volumes, we calculated the aggregate monetary in vehicle timesaving from the 10% reduction of work commute trips, using 120 SEK/hour for average hourly wage in Sweden (SIKA, 2002). This would correspond to a monetary saving of 568 million SEK for Stockholm County. If this study had been aimed at doing a cost-benefit analysis, this saving would be balanced against implementation costs, and potential losses in consumer surplus from some of the policy measures.

To give a fair estimate of the potential rebound effect from reducing transport volumes locally, we tested the effect from reducing work commute trips by

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[2] June, 2006.

30% between Stockholm and Sweden's largest telecom-business district (a district potentially fulfilling the conditions for a high telecommuting frequency). The 30% reduction of work commute trips implied an average travel time reduction of about 1%. This in turn resulted in a rebound effect of 3%, i.e. 3% of the reduced vehicle kilometres are lost due to a latent private vehicle demand. Naturally, a 30% reduction of commute trips from Stockholm to this single destination implied just a marginal effect on the total road network of Stockholm (2% reduction).

### *Travel demand measures (TDM)*

As a comparison to the potential effects of mobility management services, we also tested the effect from changing the price structure between private car and public transport. As expected, drastic increases of fuel price would have a significant impact on private vehicle travel. However, even a doubling of the fuel price would still require a mix of renewable fuels of 58% in order to reach state description C. The most substantial impact per unit of price increase observed in this study would be to increase fuel costs from 0.8 SEK/km to 2 SEK/km. It would reduce $CO_2$ emissions by 21%, which would require a mix of renewable fuel vehicles of 53% in Stockholm County. However, only a marginal relative emission impact of just 6% is evident from an additional increase in fuel price from 2 SEK/km to 3 SEK/km.

Something that is often seen as surprising, even though it is not new, is that free fare public transport did not cause a substantial impact on reduced private vehicle mileage and adherent $CO_2$ emissions. Making public transport free of charge implied just a 4% reduction of $CO_2$ emissions in comparison to state description B. The reason for this is that this policy mainly caused a shift from walking and cycling to public transport.

We tested the impact from implementing traffic tolls, similarly to what is planned for Stockholm in January 2006. Our tolls would consist of a fee of 20 SEK at peak hours and 10 SEK at off-peak hours for entering the Stockholm city centre by private car (a circle of radius 3 km). This would correspond to 0.5% of the total area of Stockholm County (6519 square kilometres). This would lead to a 9% reduction of $CO_2$–emissions and a 59% renewable fuel mix in order to reach the emission target.

We also tested the effect from enforcing a car-free inner city centre by closing down the most central streets in Stockholm from private vehicle traffic (an inner city centre of about 1 km radius, corresponding to 0.05% of Stockholm County). This would lead to a 4% reduction of $CO_2$–emissions and a required renewable fuel mix of 61% in order to reach the emission target.

Finally, it would be technically possible to enforce fuel efficiency regulations on private vehicles. Several cities (e.g. London and Paris) are considering introducing policies against “fuel-guzzlers” and subsidise “fuel-sippers”. In this study we test the effect from an average 30%, 50% and 70% fuel efficiency standard in private vehicles. As expected, this would have a considerable effect on prospects for target achievement. However, because of the improved fuel efficiency standard, car users get a reduced kilometre cost implying a clear increase in vehicle kilometres. For instance, we noticed that halving fuel consumption in private vehicles implies an adherent $CO_2$-rebound effect of almost 10%, i.e. a tenth of the positive emission reducing effect is lost as a result of the price effect from a cheaper kilometre cost. The corresponding rebound effect from a 70% fuel efficiency standard would be as high as 20%. In spite of this drastic fuel efficiency regulation, still a renewable fuel mix of 53%, 44% and 36% respectively is needed in order to reach the $CO_2$ reduction target.

## Discussion

Use of renewable fuels to the extent required for the emission target in this study will put heavy demands on future production and manufacture processes. Consequently, the competition of renewable fuels will increase in the future (Åkerman and Höjer, 2005) and most likely there will be limitations in supply, at least in the next coming decades (Azar *et al.*, 2003; Iglesias and Apsimon 2004). Thus, efficient energy use, both in the transport sector (e.g. mobility management services) and in other sectors of the society, is therefore a prerequisite for a smooth transition to a renewable fuel system. Consideration of various TDM that might help avoid over consumption and negative rebound effects is therefore of significant importance. In addition, it is likely that the price relationship between fossil fuels and renewable fuels will continue to shift till the year 2030. The price sensitivity of increased kilometre cost detected in this study indicates, in consistency with Ewing and Sarigöllü (1998), that a changed price balance between fossil and renewable fuels would substantially favour the development of renewable fuel vehicles.

It is hard to assess the future development and adoption rate of specific mobility management services. However, in this study we experiment with the macroscopic effect from hypothetical levels of reduced private car trips, commute trips and car-ownership — all associated with potential future adoption rates of mobility management services. The results indicate that on condition that mobility management services could bear their own expenses in the long run, these services might fill a certain meaning since even modest reductions of transport volumes contribute to savings in transport related costs to the society. In addition, mobility management services might induce new travel patterns and in some cases even stimulate the development of renewable fuel systems (as seen in some car-sharing fleets and public transport systems today). However, economic feasibility, investment costs and practical implementation are left beyond the scope of this study. We focus on the potential effectiveness of the various mobility management services and TDM as tools for reaching the emission-target for 2030, and a few adherent positive side effects. Nevertheless, to make a complete cost benefit analysis of the different policy alternatives, each of the positive economic side effects presented in this study must be weighted against investment costs and maintenance costs for both short and longer time frames, and against potential losses in consumer surplus due to price changes and other measures.

Examples of mobility management services, hypothetically assisting the conditions in state description C, are car-sharing, ride-matching, telecommuting, meeting policies, videoconferencing and public transport. The Swedish National Road Administration (SNRA, 2003) conducted a national survey revealing that about 20% of Swedish households are interested in joining a car-sharing facility. SNRA (2003) further refer to a study by Muheim (1998), concluding that the potential for car-sharing in Switzerland is almost 10%, a figure that, according to SNRA (2003) could be used with caution even for Sweden. Regarding the potential $CO_2$ reduction, SNRA (2003) conclude that one CS-vehicle substitutes approximately 5 private cars and implies about 380 kg $CO_2$ reduction per car-sharing member (or 6600 tons $CO_2$ reduction per car-sharing vehicle and year).

Naturally, the potential for mobility management services is higher in a densely populated city like Stockholm than in Sweden in general. Robèrt (2005)conducted a stated preference survey in one of Stockholm's larger business districts (Nacka Strand) and identified potential winwin situations where both the employees and the employer would save travel expenses from an extended use of new mobility management alternatives. More than half of the respondents stated that they where willing to substitute present car- and taxi trips with mobility management services such as car-sharing and ride matching. The employees were also positively disposed toward more frequent telecommuting and videoconferencing. Even though telecommuting was well implemented at the companies, a majority of the respondents stated they were willing to telecommute even more than at present (Robèrt and Börjesson, 2005). Arnfalk (2002) refers to two alternative predictions of future telecommuting potential in Stockholm, concluding that telecommuting has the potential to substitute work commute in the range of 6% (Paavonen, 2000) to 25–30% (City of Stockholm, 1995).

SNRA (2003) concludes that the greatest strength of mobility management services (e.g. car-sharing) is probably of a structural nature, facilitating use of public transport and inducing more effective car use. The exact substitution rate is therefore hard to predict, especially in a future scenario, since it depends on the interaction with other travel modes, changed travel patterns and new price structures. It is likely that the adoption rate of new mobility management alternatives increases in relation to the TDM tested in this study (e.g. increased fuel prices and traffic tolls).

What proportions of the specific mobility services and other TDM must be required to fulfil the reduction levels experimented upon in this study, and specifically, what measures should be prioritized over the other? Based on the forecasts mentioned above, and from our results from the business district in Stockholm, a reduction of work-related travel of at least 10% (from all types of mobility management alternatives) might be a fair assumption for 2030. The results in this study show that work related travel corresponds to the far most substantial part of private vehicle kilometres. Consequently, testing attitudes and preferences towards new travel policies and new mobility alternatives at companies are of great importance in order to incorporate mobility management alternatives as an efficient TDM (Robèrt, 2003). Company travel plans (i.e. development of more sustainable work related travel) might play an essential role for sustainable development (Robèrt, 2005; Rye, 2002; Coleman, 2000).

As expected, a clear fuel price sensitivity was evident. However, the effect from making public transport free of charge was perhaps not as substantial as expected. Brown *et al.*, (2003) show, in a before- and after study, a vast impact on mode choice from fare-free public transport in Los Angeles. Public transport to the university of California (UCLA) increased by 56% and solo-driving fell by 20%. Perhaps the differences in results between these two studies could be explained by the fact that Stockholm has a relatively higher share of public transport use.

Both traffic tolls and enforcement of a car-free city centre implied just a minor effect on reaching the emission target (merely a 9% reduction from the introduction of traffic tolls and a 4% reduction from the car-free city centre). Yet, considering that the area enclosed by traffic tolls in this study only cover 0.5% of Stockholm county (Stockholm, 2004), and that the car-free city centre would cover only about 0,05%, these two travel demand measures highlight the relatively large impact from actions taken locally in the most congested part of the transport network. Naturally, since traffic tolls and car-free streets in the city centre are limited to just the core of Stockholm County, it is difficult to compare the $CO_2$ reduction effect from these measures to other TDM tested in this study. The largest impact from transport reducing measures in the city centre is perhaps seen in reduced walking/cycling accidents and from increased health and comfort aspects from cleaner air in the city. This in turn, corresponds to savings in emission- and accident costs (e.g. savings in emission and accident costs from traffic tolls would amount to 1.14 billion SEK).

Two different types of rebound effects were detected. Firstly, our experiment with reducing transport volumes locally between Stockholm and a large business district, revealed a latent car demand filling part of the vacant space in the transport network. This 3% rebound effect does not appear substantial enough for giving up the idea of telecommuting as a transport reducing policy, at least on the margin. However, telecommuting might also be coupled to other types of rebound effects. Potentially, telecommuters might use some of the lost commuting time to other types of trips and errands (Mokhtarian and Salomon, 2002; Mokhtarian, 1997; TDM Encyklopedia, 2004; Arnfalk, 2002).

Secondly, in consistency with (Jones, 1993), (Greene *et al.*, 1999) and (Berkhout *et al.*, 2000), the results in this study indicate rebound effects from fuel efficiency regulations. Nevertheless, since the fuel efficiency regulations appeared to be quite effective, it could still play an important role in assisting the emission target 2030. In addition, from the fuel price sensitivity detected, both types of rebound effects could be counteracted by fuel taxes and other TDM experimented with in this study.

## Conclusions

At a first glance, from a pure emission reduction point of view, mobility management services and other TDM seem to bring just a modest impact on reaching the $CO_2$ target in comparison to the required share of renewable fuel vehicles 2030. In spite of the drastic regulations experimented with in this study, a renewable fuel mix of at least 50% is required in order to reach target fulfilment (except in the two most drastic energy efficiency scenarios). In the longer-term target in the year 2050, renewable fuels are inherently needed since the target is then zero fossil $CO_2$ emissions (Fig. 2). This introduces a strategic dimension to the concluded 50% renewable fuel mix by the year 2030. The transition ought to be started in due time and in a way that allows the investments up to 2030 to serve as flexible platforms for the remaining period to 2050. Thus, from a strategic backcasting point of view, the transport reducing policies might contribute *indirectly* to target achievement. Furthermore, even small reductions of transport volumes might imply large savings in traffic related costs from emissions, accidents and in vehicle times — savings that should be kept in mind when discussing investment costs of infrastructure and renewable energy systems for the future.

A combination of carrots (e.g. renewable fuel vehicles and mobility management services) and sticks (e.g. increased price on fossil fuels and various TDM) might imply synergy effects and is likely more effective than employing one of the two strategy-types solely. In the process toward a sustainable transport system it is crucial to find alternative ways of reducing car dependence (Cullinane and Cullinane, 2003). One should not underestimate the potential of many small contributions and in the unsustainable transport system of today, one must allow experimentation with hypothetical trend breakers. It is hard to foresee potential snowballing effects and synergy effects that might arise if increased user rates of new alternatives reach certain threshold levels where e.g. more car-sharing vehicles, ride-matching commuters, telecommuters or videoconference facilities might increase the power of attraction of the services, implying positive feedback loops. But identifying such loops before that critical threshold is very difficult.

The target-oriented backcasting framework developed in this is study is well suited for integrating policymakers from different angles in the dialogue since it keeps track of the total picture even though each specific alternative action is analysed in detail. In order to create an illustrative map of state descriptions, between which feasible backcasting paths could be drawn, decision makers inevitably get confronted with the questions: Where are we now? Where are we heading if no target-oriented actions are taken? Where would we like to go, i.e. what target is set? What can we do to get there? What measures should be prioritized over the other, considering key aspects such as the emission reduction potential, long- and short term economic payback, social aspects, etc.?

As a consequence, decision makers and stake holders might challenge transport modellers, raising the question: How could we utilize and develop present transport forecasting models, mainly used for cost-benefit assessment of new infrastructure investments, to also work as a target oriented path-finder toward sustainability criterions in a backcasting framework?

Future potential and development of more resource efficient mobility needs further research. In this study we have employed a transport analysis system where mobility management services or renewable fuel vehicles are not incorporated as alternatives to traditional travel modes. Instead we estimate the *potential* impact from these travel alternatives by reducing certain proportions of total transport volumes, work related travel and car-ownership, basing our assumptions on former research and literature studies. Moreover, we conclude that if the aim were to derive the most optimal *combination* of travel policies, the number of alternative backcasting paths would have been large and it would have been necessary to introduce some sort of ranking system (e.g. optimizing an objective function over all feasible policy sets).

# APPENDIX

## The effect model

We derive the emissions generated in the road network from the following relationship:

$$E_j^* = \sum_i \sum_k f_{ik}^* l_i \alpha_j \beta_k \gamma_{jk}(v_i^*) \tag{A.1}$$

$E_j^*$ = emission per hour of each of the gases, represented by index $j$ ($CO_2$, $NO_x$, HC, $SO_2$, particles), from the transport network in Stockholm per hour. The super index * represents peak hour (PH) and off-peak hour (OPH).

$i$ = link number

$k$ = vehicle type (private cars, light lorries, heavy lorries, trailer lorries).

$f_{ik}^*$ = flow of vehicle type $k$ on link $i$ per hour.

$l_i$ = length of link $i$.

$\alpha_j$ = factor transforming $CO_2$ emissions into $CO_2$ equivalents (SNRA, 2004). Equal to one for other emissions.

$\beta_k$ = factor compensating for different proportions of petrol-driven and diesel-driven private vehicles in the road network for vehicle type $k$ (SNRA, 2001). Equals 1 for lorries.

$\gamma_{kj}(v_i^*)$ = emission factor for gas $j$ for vehicle type $k$ at vehicle speed $v$ at link $i$ for peak hour and off peak hour, respectively (Biding and Lindqvist, 2005)[3].

To calculate daily and yearly emissions from the transport network of Stockholm, we use an approximation applied by the Swedish National Road Administration (Biding and Lindqvist, 2005):

$$E_{j,year} = 365 * \left(4E_j^{PH} + 10E_j^{OPH}\right) \tag{A.2}$$

where $E_j^{PH}$ is emission per hour at peak hours, and $E_j^{OP}$ emission per hour at off-peak hours.

When calculating the costs for the emitted gases, we use standard values developed by SIKA (2002) and (Persson and Lindqvist, 2003).

The emission costs per hour $C_h^*$ are then derived from a similar expression as Eq. 1:

$$C_h^* = \sum_i \sum_k \sum_j f_{ik}^* l_i \beta_k \gamma_{kj}(v_i^*) \sigma_{ij} \tag{A.3}$$

$\sigma_{ij}$ = socio economic cost for emitting gas $j$ at link $i$. The term $\sigma_{ij}$ is link-based, allowing us to assign relatively higher emission costs at low-speed roads in the city centre than in more peripheral areas (as a consequence of that more people get exposed to the toxic exhaust fumes in densely populated areas).

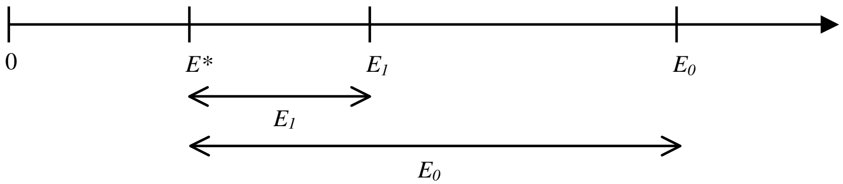
Total socioeconomic costs from *emissions*, *accidents* and *in vehicle time*, generated in the road network per year is finally derived from:

$$C_{tot} = C_{emission} + \lambda(f) + \sum_i f_i^{year} \frac{l_i}{v_i} \delta \qquad \text{(A.4)}$$

$C_{tot}$ = costs from emissions, accidents and in vehicle time.
$C_{emission}$ = emission costs per year (derived through Eq. 2, using $C_h^*$ instead of $E_h^*$).
$\lambda(f)$ = accident costs, assumed proportional to vehicle flows $f$ in the road network.
$f_i^{year}$ = traffic flow per year at link $i$.
$\delta$ = 120 SEK/hour for average hourly wage in Sweden (SIKA, 2002).

## Estimation of the rebound effect

In Fig. A.1 below, the rebound effect is visualized graphically. $E_0$ is the situation before the efficiency change is introduced (in this study caused by reduced fuel consumption or reduced transport volumes). The rebound effect is then the difference between the emission level after the efficiency change is introduced ($E_1$), and the emission level that would have been achieved in a hypothetical scenario where the transport demand is held constant in spite of the efficiency change ($E^*$). The relative rebound effect (RE) is the ratio between the absolute size of the rebound effect ($\Delta E_1$) and the hypothetical effect ($\Delta E_0$). This is the standard definition to the rebound effect, most commonly expressed in percent (Berkhout *et al.*, 2000).



$E_0$ = Energy reference level without the energy efficiency
$E_1$ = Energy level achieved after efficiency is introduced
$E^*$= Energy level achieved in a virtual scenario without rebound effects
$\Delta E_1 = E_1 - E^*$
$\Delta E_0 = E_0 - E^*$
$RE = \Delta E_1 / \Delta E_0 = (E_1 - E^*) / (E_0 - E^*)$

Fig. A.1.

## Results

### State description A

Table 1.

| Effect estimations (per year) | Stockholm transport system | Private cars |
|---|---|---|
| $CO_2$ equivalents (million tons) | 2.11 | 1.46 |
| $CO_2$ equivalents per capita (tons) | 1.17 | 0.81 |
| $NO_x$ (ktons) | 10.00 | 2.72 |
| HC (ktons) | 4.98 | 3.58 |
| Particles (ktons) | 0.295 | 0.034 |
| $SO_2$ (ktons) | 0.044 | 0.031 |
| Emission costs* (billion SEK) | 4.40 | 2.59 |
| Private car kilometres (billion km) | 6.15 | 6.15 |
| Accident costs (billion SEK) | 7.00 | |

*Socio economic costs for $CO_2$, $NO_x$, HC, Particles, $SO_2$.

### State description B

Table 2.

| Effect estimations (per year) | Stockholm transport system | Private cars only |
|---|---|---|
| $CO_2$ equivalents (million tons) | 2.27 | 1.72 |
| $CO_2$ equivalents per capita (tons) | 0.94 | 0.72 |
| $NO_x$ (ktons) | 3.13 | 0.96 |
| HC (ktons) | 2.11 | 1.35 |
| Particles (ktons) | 0.070 | 0.028 |
| $SO_2$ (ktons) | 0.048 | 0.036 |
| Emission costs (billion SEK) | 4.13 | 2.74 |
| Private car kilometres (billion km) | 7.87 | 7.87 |
| $CO_2$ exceeding target (million tons) | 1.42 | |
| Accident costs (billion SEK) | 8.96 | |
| $CO_2$ increase in comparison to A | 7% | |
| Required renewable fuel mix | 63% | |

### *Backcasting paths to state description C*

### Reduced transport volumes

Table 3. Reduction of private car trips.

| Level of reduction | 10% | 20% | 30% |
|---|---|---|---|
| $CO_2$ equivalents from total transport system (million tons) | 2.07 | 1.87 | 1.70 |
| $CO_2$ equivalents from total transport system per capita (tons) | 0.86 | 0.78 | 0.71 |
| $CO_2$equivalents exceeding target achievement (million tons) | 1.23 | 1.03 | 0.86 |
| Annual emission cost (billion SEK) | 3.77 | 3.40 | 3.09 |
| Annual accident cost (billion SEK) | 8.21 | 7.46 | 6.80 |
| $CO_2$ reduction compared to state description B | −8% | −17% | −24% |
| Required renewable fuel mix to reach target fulfilment | 59% | 55% | 51% |

Table 4. Reduction of work commute and local business trips.

| Level of reduction | 10% | 20% | 30% |
|---|---|---|---|
| $CO_2$ equivalents from total transport system (million tons) | 2.13 | 1.99 | 1.88 |
| $CO_2$ equivalents from total transport system per capita (tons) | 0.89 | 0.83 | 0.78 |
| $CO_2$ equivalents exceeding target achievement (million tons) | 1.29 | 1.15 | 1.04 |
| Annual emission cost (billion SEK) | 3.88 | 3.63 | 3.43 |
| Annual accident cost (billion SEK) | 8.45 | 7.95 | 7.53 |
| $CO_2$ reduction compared to state description B | −5% | −12% | −16% |
| Required renewable fuel mix to reach target fulfilment | 61% | 58% | 55% |

Table 5. Reduction of car ownership.

| Level of reduction | 10% | 20% |
|---|---|---|
| $CO_2$ equivalents from total transport system (million tons) | 2.14 | 1.98 |
| $CO_2$ equivalents from total transport system per capita (tons) | 0.89 | 0.83 |
| $CO_2$ equivalents exceeding target achievement (million tons) | 1.30 | 1.15 |
| Annual emission cost (billion SEK) | 3.90 | 3.61 |
| Annual accident cost (billion SEK) | 8.44 | 7.86 |
| $CO_2$ reduction compared to state description B | −6% | −13% |
| Required renewable fuel mix to reach target fulfilment | 61% | 58% |

Table 6. Reduced commuting to Kista.

| | |
|---|---|
| 30% reduction of private car commuting to Kista | 2.23 |
| $CO_2$ equivalents from total transport system (million tons) | 2.23 |
| $CO_2$ equivalents from total transport system per capita (tons) | 0.93 |
| $CO_2$ equivalents exceeding target achievment (million tons) | 1.39 |
| Emission cost (billion SEK) | 4.06 |
| Accident cost (billion SEK) | 8.80 |
| Private car kilometres (billion km) | 8.59 |
| $CO_2$ reduction compared to state description B | −2% |
| Required renewable fuel mix to reach target fulfilment | 62% |
| Calculated rebound effect (increased transport volumes caused by reduced travel times) | 3% |

## Travel demand measures

Table 7. Increased fuel price.

| Fuel price (base level = 0.8 SEK/km) | 1.5 SEK/km | 2 SEK/km | 3 SEK/km |
|---|---|---|---|
| $CO_2$ equivalents from total transport system (million tons) | 2.02 | 1.79 | 1.68 |
| $CO_2$ equivalents from total transport system per capita (tons) | 0.84 | 0.74 | 0.70 |
| $CO_2$ equivalents exceeding target achievement (million tons) | 1.18 | 0.94 | 0.84 |
| Annual emission cost (billion SEK) | 3.69 | 3.26 | 3.07 |
| Annual accident cost (billion SEK) | 7.98 | 7.06 | 6.57 |
| $CO_2$ reduction compared to state description B | −11% | −21% | −26% |
| Required renewable fuel mix to reach target fulfilment | 58% | 53% | 50% |

Table 8. Free fare public transport.

| | |
|---|---|
| $CO_2$ equivalents from total transport system (million tons) | 2.19 |
| $CO_2$ equivalents from total transport system per capita (tons) | 0.91 |
| $CO_2$ equivalents exceeding target achievement (million tons) | 1.34 |
| Annual emission cost (billion SEK) | 4.00 |
| Annual accident cost (billion SEK) | 8.69 |
| $CO_2$ reduction compared to state description B | −4% |
| Required renewable fuel mix to reach target fulfilment | 61% |

Table 9. Traffic tolls.

| | |
|---|---|
| $CO_2$ equivalents from total transport system (million tons) | 2.07 |
| $CO_2$ equivalents from total transport system per capita (tons) | 0.86 |
| $CO_2$ equivalents exceeding target achievement (million tons) | 1.22 |
| Annual emission cost (billion SEK) | 3.77 |
| Annual accident cost (billion SEK) | 8.18 |
| $CO_2$ reduction compared to state description B | −9% |
| Required renewable fuel mix to reach target fulfilment | 59% |

Table 10. Increased fuel efficiency in private cars.

| Efficiency level | 30% | 50% | 70% |
|---|---|---|---|
| $CO_2$ equivalents from total transport system (million tons) | 1.78 | 1.49 | 1.31 |
| $CO_2$ equivalents from total transport system per capita (tons) | 0.74 | 0.62 | 0.55 |
| $CO_2$ equivalents exceeding target achievement (million tons) | 0.94 | 0.65 | 0,47 |
| Annual emission cost (billion SEK) | 3.38 | 2.92 | 2,78 |
| Annual accident cost (billion SEK) | 9.15 | 9.47 | 10.95 |
| $CO_2$ reduction compared to state description B | −21% | −34% | −42% |
| Required renewable fuel mix to reach target fulfilment | 53% | 44% | 36% |
| Calculated $CO_2$ rebound effect (total transport system) | 6% | 10% | −20% |

Table 11. Car-free city centre.

| Car-free city centre | |
|---|---|
| $CO_2$ equivalents from total transport system (million tons) | 2.17 |
| $CO_2$ equivalents from total transport system per capita (tons) | 0.90 |
| $CO_2$ equivalents exceeding target achievment (million tons) | 1.32 |
| Emission cost (billion SEK) | 3.95 |
| Accident cost (billion SEK) | 8.61 |
| Private car kilometres (billion km) | 8.40 |
| $CO_2$ reduction compared to state description B | −4% |
| Required renewable fuel mix to reach target fulfilment | −61% |

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