THE MAN WHO ATE THE WORLD

An inquiry into the potential for decoupling economic growth and environmental impacts

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While there has long been a debate in academia, politics as well as society at large regarding the need to reduce the harmful effects on nature caused by mankind's increasing levels of consumption, it is only within recent years that political consensus has been reached on the matter of changes in global ecosystems being attributed to anthropogenic causes. This study seeks to investigate the relationship between economic growth and environmental impacts from the activities required to facilitate such growth by analyzing recent experience from the transport sector. Three scenarios for potential decoupling strategies are constructed in order to evaluate appropriate action, and whether a decoupling does at all seem likely under the current structure of modern economies. Results are not particularly optimistic in this regard due to limitations of the decoupling potential in all three scenarios, as well as negative societal consequences that could arise from intense pursuit of such strategies. It is therefore argued that the foundations of economic growth in its current form are in need of a severe restructuring if sustainable development is to be achieved without fear of a future economic and ecological collapse.

Preface

This report is the result of the study programme with which I have been involved during the past nine months, from September 2008 until early June 2009, as a Master Student at Department of Development and Planning, Aalborg University. Inspiration for the topic of this thesis has however been gathered over a much longer timeframe, e.g. from discussions with family, friends and fellow students, and of course also from the various study programmes I have attended during my time at Aalborg University. A few particular sources of inspiration deserves special mentioning here however, as they have meant a great deal to me during the process of completing this project.

The first would be my aunt Anette Nicolaisen, whom at an early age introduced me to the writings of Robert M. Pirsig and Fernando Savater, which I was far too young to fully appreciate at the time. As time has gone by however, I have discovered that their thoughts have influenced my own quite substantially, and have ignited a desire for further reflection on the quality of individuals and society.

The second would be my supervisor Petter Næss, who has been an invaluable asset due to his function as both mentor and critic. He has provided useful input throughout the entire study process, shown great interest in my work in general and put far more effort and hours in the task of supervising than what can be required from any student. Due to this I have never felt any signs of frustration or considered the task of studying a significant burden. That being said I of course bear the sole responsibility for any potential errors or shortcomings in this report.

Special thanks of course go to those closest to me that have supported me in my studies, even if I it has not always been perfectly clear to them where I was heading.

Morten Skou Nicolaisen

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Contents

1 Introduction

In this first chapter I will provide a general introduction to the overall topic of this report, which is sustainable mobility in the context of economic growth. What is understood by growth? What is understood by sustainable mobility? Why is it relevant to study the relationship between growth and sustainability? These are some of the questions that will be answered throughout this introduction. In addition to this I will also try to clarify throughout this first chapter what my normative standpoint is and how it is reflected in this study. This includes comments on what methods have been used as well as the rationale behind choosing them. The chapter will end up by summarizing the structure and content of the individual chapters of the report.

1.1 Who is eating the earth?

As a start I'd like to explain the somewhat peculiar title of this work. 'The man who ate the world' is originally a work of fiction by Frederik Pohl written half a century ago, of which I have shamelessly copied the title for this report. Not in an attempt of plagiarism obviously, as a science fiction novel bears little resemblance with the work of a planning student aiming to find a sustainable path to economic growth... or at least with the work a planning student aiming to find a sustainable path to economic growth while adhering to Comte's enigmatic ideals of positivism. I do not consider myself such a student however, and the novel has instead served as yet another inspiration on how the future of modern society could be shaped. Pohl's tale is of a society in which consumption has become the goal of life itself, and with the danger of immediately being dismissed as 'another eco-hippie' by drawing from such inspiration I would argue that a similar trend has been present within modern society for quite some time now, which is also true for the transport sector. The current recession is an illustrating example of what happens when the hamster slows down on the treadmill; governments across the world try to pour whatever penny they can spare into the system to kick-start the economy since a slowed economy equals reduced spending, which ultimately results in less consumption. The wheels must keep turning and the economy must thus keep growing.

For the transport sector economic growth has traditionally meant roughly equal growth in transport volumes, so a plan to ensure continued economic growth is thus also a plan that is accompanied by increasing transport volumes, which are then followed by increasing emission levels from the extra transport activity. The term growth, as used here, relates to economic activity measured in GDP, which has been the traditional unit of observation when judging economic capacity. As the aim of this report is to analyse the decoupling potential of economic growth and the adverse environmental effects of transport, this growth definition will also be used in the analysis of this report. However, like the man who ate the world transport too is eating up the resources of the earth, both in terms of material input to produce it and the spatial constraints it imposes through infrastructure. If a decoupling approach proves unable to cope with the requirements for reduction then the concept of growth outlined above would need to be revised. A discussion of such revision will take place in the chapters placed after the scenarios.

1.2 What's it all about then?

The overall theme of this report is an analysis of the effectiveness of current attempts to achieve a more sustainable mobility development through decoupling between growth in GDP, transport and CO_2 emissions, which have had very similar growth rates over the past decades. The correlation between the above three factors has been reflected in traditional transport literature for a long time now, but so far a successful decoupling strategy has yet to be found in spite of great amounts of research directed towards this problem as well as various technological advances within the transport sector. This decoupling is generally seen as a requirement if one of the core foundations of western capitalist societies is to be maintained in the future, which is that of continued economic growth. Whether such a decoupling is at all possible will be the focus of a discussion presented at the end of this report.

The uncertainties regarding mankind's contribution to global warming have decreased rapidly over the past three decades, partly due to recent major climate events hinting at the potential consequences of continuously increasing consumption levels. As Gro Harlem Brundtland phrased it very well in her opening address at the Beyond Kyoto conference in Århus (Denmark) 2009: "*the time for diagnosis is over; now is the time to act*". Ecological sustainability has come to play a bigger role in the development discussions within many sectors as a result of this, and especially so in the transport sector which accounts for about a third of the total CO_2 emissions in the EU (T&E, 2008), and this share is rising steadily. Emissions in the European transport sector have increased by 34% from 1990-2006, while other sectors managed a 3% reduction in the same period (T&E, 2008). As the transport sector's share of total CO_2 emission is increasing rapidly, drastic changes are needed if economic growth is to continue without causing unacceptable consequences for the environment of our planet. In Denmark the increasing energy consumption of the transport sector is solely responsible for an increasing CO_2 emission, where increasing transport volumes for road traffic, international airlines and military services outweighs the reduction in the rail, sea and national airline traffic by a large margin (Energistyrelsen, 2008).

In this report I will analyse a set of scenarios concerning how a potential decoupling can be achieved, which are based on the approaches that have gained the most attention in academia, politics and media alike. These scenarios can be split into three rather crude categories, which I have chosen to name technology, modal switch and reduction, and will be compared to a business as usual scenario (BAU) for reference purposes. The BAU scenario is based on extrapolation of the development in Denmark over the past decades, while the three other scenarios are based on previous studies involving scenario construction along with best case examples from other countries that have implemented some of the characteristic features of the given scenario. The purpose of these scenarios is to form the basis of a comparative analysis of the different scenarios and their potential for decoupling GDP, traffic and CO_2, along with an evaluation of their respective economic, social and environmental consequences that could result from such approaches. The drastic changes that seem to be required in order to achieve a decoupling must be expected to have an equally drastic impact on the societies where these changes are meant to take place. If the societal consequences are too high is a decoupling then desirable at all, or should we instead reconsider economic growth as the premise of our capitalist society?

1.3 Coupling and decoupling unveiled

There is general consensus in the transport literature that GDP, traffic and CO_2 are indeed coupled. Of course the degree of coupling varies both over time and between different geographical locations, but the general tendency is that the three are strongly correlated. Looking at figure 1 it is easy to see that this is the case in Denmark as well. The figure shows the development from 1994 to 2004 for road and rail transport in Denmark, with GDP measured in constant 2000 prices and traffic measured as vehicle kilometres driven.

If we look at the EU15 countries the picture is basically the same, although with slight variations between the different countries. Tapio (2005) presents results on the degree of decoupling in the EU15 countries in the period 1970-2000, in which he categorises the development as negative decoupling, expansive coupling or weak decoupling depending on the GDP elasticity of traffic volume for each country during the three decades. The three categories are further explained in Table 1.

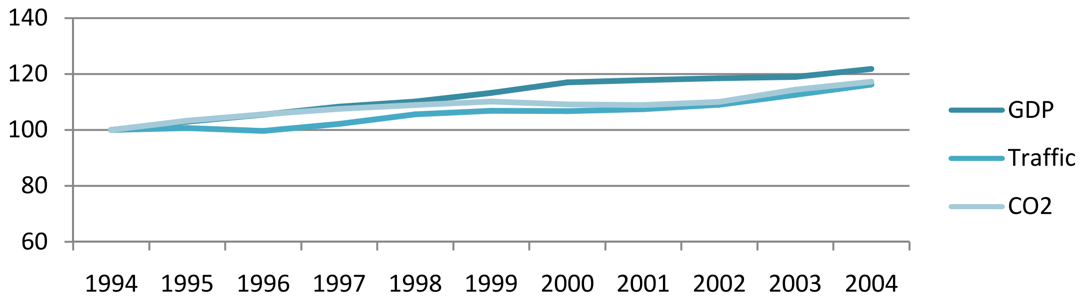

Figure 1: Coupling in Denmark 1994-2004. Based on data from Statistikbanken (2008)

Category	ΔGDP/ΔVOL	Description
Weak decoupling	>1.2	High elasticity, transport volume growth is slower than economic growth.
Expansive coupling	0.8-1.2	Medium elasticity, transport volume and economy grow at similar rates.
Negative decoupling	0.0-0.8	Low elasticity, transport volume growth is faster than economic growth.

Table 1: The three development categories used to describe the EU 15 countries.

Now, the important part about the categories listed in table 1 is that all of them describe an expansive development in which both the change in traffic volume (ΔVOL) and economic activity (ΔGDP) have been positive. Other categories are used to describe recessive or strong decoupling scenarios in which either ΔVOL<0 or ΔGDP<0, but development in all EU15 countries have been expansive in the period used for this study and as such these are of little relevance here. Tapio found that decoupling has been weak at best during this period in all member countries, and more often development has either been categorised as expansive coupling or expansive negative decoupling, meaning GDP elasticity ratios of 1.2 or below. The general results can be found in figure 2, from which it can be seen that of the 15 EU countries only six have managed a weak decoupling of GDP and traffic in the 90s. None of the countries have managed to reach a strong decoupling (elasticity ratios below zero), and if we examine the numbers behind this we would find that some of the countries that have their development categorised as weak decoupling are very close to the threshold value for expansive coupling. Overall, only indications of slight relative decoupling can be identified, with no indications of absolute decoupling whatsoever.

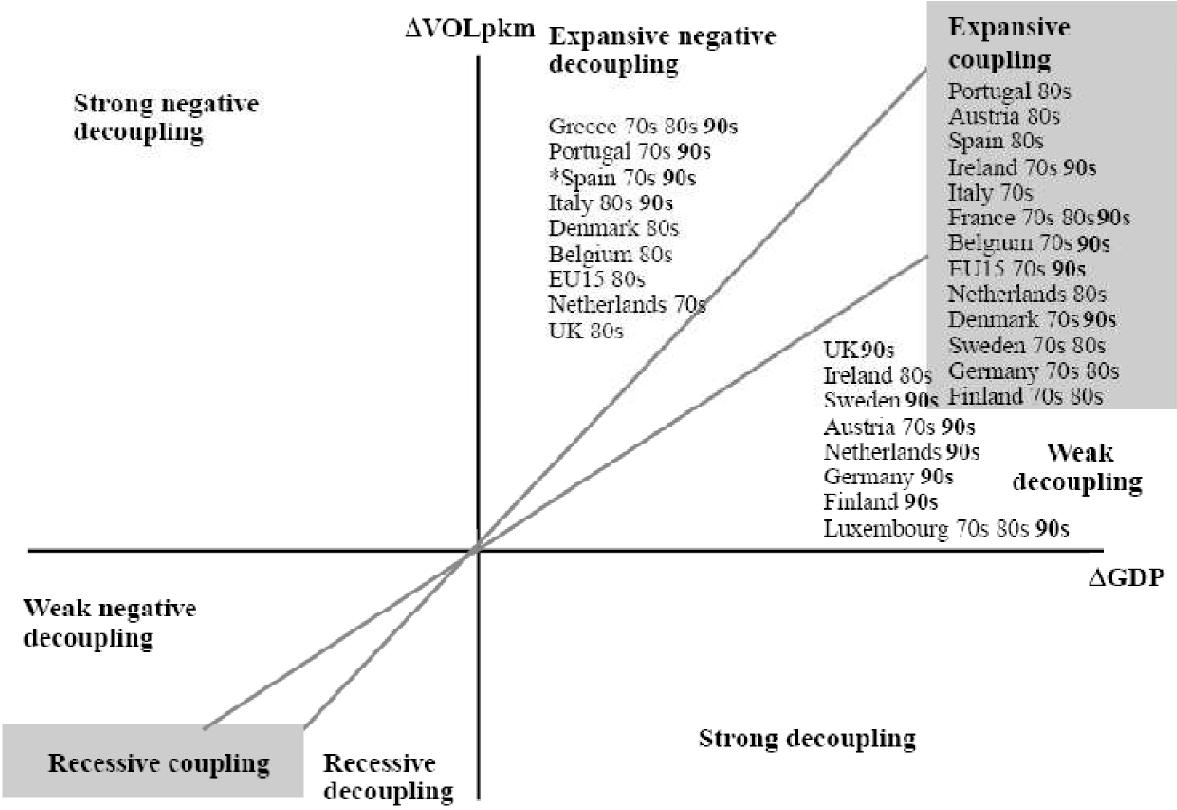

Figure 2: Development trends in EU15 in the period 1970-2000 based on the GPD elasticity of traffic volume measured in passenger kilometres travelled (VOL) (Tapio, 2005).

Here it is important to note that figure 2 illustrates the degree of decoupling between GDP and traffic volume, while this project is mainly concerned with a decoupling between GDP and the adverse environmental effects of transport. Decoupling of GDP and traffic volume is thus just one step in a two-step process where decoupling between traffic volume and environmental effects would be the other. As we shall see later in this report the different scenarios focus on different steps in the decoupling process, but the coupling trend for traffic volume and environmental impact show similar development to that illustrated for GDP and traffic volume here.

1.4 Towards sustainable mobility

It seems reasonable to conclude from the data in the previous section that development in the EU15 countries so far does not seem to indicate a desirable decoupling of GDP and traffic in the near future, unless we engage ourselves more actively with if and how such a decoupling is to take place. In fact the Mediterranean EU15 countries show a discouraging trend of higher growth in traffic volume than GDP during the last decade. The point of departure for this report is thus the assumption that the current development is insufficient for creating a sustainable mobility future. Sustainable mobility can of course not be reduced to a simple set of indicators such as traffic volume or CO_2, but as these are at least minimum requirements for achieving sustainability in the transport sector I have chosen to keep my main focus on these in this report[1].

Briefly explained sustainability is here understood as a situation in which consumption and emission levels do not limit the possibilities for future generations to continue such levels without causing drastic changes to the environment and reducing the capacity of earth's ecosystem. The CO_2 emission from the transport sector is just one aspect of a sustainable development discourse, but a single aspect can nonetheless require a complex set of solutions if sustainability is to be achieved, which will hopefully become clear during this report. Apart from the potential technological advances and social restructuring that can help reduce emission levels there is also a more directly influencing factor that often seems to be forgotten, which is the size of the consumer base that is creating the demand for increasing amounts of transport and thus emission levels. The global population is increasing rapidly while technological advances in the healthcare sector extend the lifespan of the people that are currently occupying the planet. All of them put an increasing demand on consumption levels, and not only in the transport sector. A simple equation crudely illustrates the connection between our energy consumption (E), technological efficiency (T), affluence level (A) and population size (P): $E=P \cdot A \cdot T$ (Commoner, 1971). The problem here is that "*the dominant discourse seem to focus quite one-sidedly on the T factor*" (Næss, 2008), while affluence levels and population growth are hardly ever questioned. It is not the intention of this report to stretch into the field of overpopulation or other energy demanding sectors than transport. However, I have mentioned them here to serve as a reminder that technological improvements need to be increased by such a huge margin that it seems improbable that technology alone can overcome the barriers of sustainable

[1] One is unsustainable due to global warming, the other due to spatial constraints.

development as a whole, and thus also for the subcategory of sustainable mobility with which this report is primarily concerned. A doubling of transport demand over a period of x years would require a doubling of efficiency as well just to keep emissions at status quo, but sustainability does not have a timeframe of only x years. Embedded in the idiom ‘sustainability’ lies a timeframe that stretches far beyond x no matter what size we give it, and after five periods we would need an efficiency increase of factor 32 to keep status quo on emissions. After 10 periods it would be a factor 1024. Hopefully it seems obvious from this that there are some inherent problems connected to such an approach.

The reason behind my cautiousness in regards to technological advance as a sustainability saviour is not that I do not believe in benefits from efficiency improvements at all; I merely do not consider them sufficient. Theories of ecological modernisation, green capitalism and dematerialization have helped promote technological advance as the primary method of reducing environmental impacts, and while efficiency improvements in itself is certainly a desirable thing to aim for, then these theories also serve to justify a lack of involvement with other ways of reducing environmental strain. In the transport sector this could be through a reduction of travel demand, which has largely been ignored as an instrument by many governments due to the lack of public support it often involves. The problematic issues in relation to ecological modernisation will be discussed further in section 2.4.

1.5 Studying the future

It should be clear by now that this report will engage in futures studies of some sort as the scenarios are intended to reflect possible outcomes of the three decision making policies that are given the most attention. Predicting the future has been of interest to mankind for millennia, and while the techniques have varied through time we have never really managed to come up with a sure proof method of prediction. We do however have a set of tools available that can help us illustrate likely future outcomes of following a specific strategy, which enables us to at least become aware of some of the potential benefits and hazards associated with doing so. I have chosen to approach the challenge of sustainable mobility through a scenario approach in which the different scenarios are supposed to reflect the primary strategies that are either being deployed or discussed in contemporary transport planning and policy making. Scenarios can be said to be *“more analytical than fiction, but more opportunity seeking than the prognosis”* (Guttu, 1993), and it is exactly these characteristics I consider important for futures studies in relation to environmental concerns. We will gain little from fictionist tales of an ecological utopia as the path to it would be hard to find, and pure forecasting would only leave us with an idea of how things will be if we do not change the current development. What we need are images of realistic, potential futures based on both forecasting and backcasting, which enables us to bring recommendations of how to achieve such futures as well as awareness of the problematic issues that could arise from doing so.

The scenarios are meant to illustrate alternate futures that these various planning strategies are likely to result in if implemented, with the intention of evaluating their chances of successfully decoupling GDP, transport and CO_2. The BAU scenario will be based on current Danish trends as mentioned previously, while the other scenarios are inspired by the recently published report on the future of Danish infrastructure by the Danish commission on infrastructure (Infrastrukturkommissionen) published January 2008, the Fingerplan 2007 whitepaper and the Regionplan 2005 whitepaper (Infrastrukturkommissionen, 2008; Fingerplan 2007; Regionplan 2005). This report is an example of traditional infrastructure planning with a high degree of attention towards technological improvements and expansion of the existing infrastructure network, as the means to solve problems of both congestion and pollution in the transport sector, and was intended as a basis for the discussion of physical infrastructure planning towards 2030 in Denmark. In order to evaluate the potential for successful decoupling in the various scenarios a set of sustainability goals are also needed. These goals will be based on the concept of a Sustainable Mobility Area (Holden, 2007) and outlined in chapter 2. The scenario building process will thus also include considerations of the changes required to reach these goals in order to evaluate the desirability of the different strategies from a societal perspective. The scenario building will be explained in further detail in chapter2.

1.6 Comments on methodology

Most of the empirical data presented in the scenarios will not be produced by me, as the amount of data required to construct and compare these scenarios in my opinion would be in poor proportion with the timeframe of this project, if I were to produce it all myself. Furthermore, plenty of data is readily available at the time of this writing, and I would thus feel like contributing very little by reproducing these results; especially when the actual scope of this project is to construct scenarios to serve as a basis for a discussion on the viability of decoupling and economic growth in general. I have thus almost exclusively drawn on results from other authors and tried to put them into the context of the sustainable mobility discussion. Would the results of this report have benefited from the addition of my own data sets? I doubt it, and in any case it would have resulted in greatly reduced interdisciplinarity, which I hope is what will prove to be the strength of this report instead. I have included both quantitative and qualitative contributions from academic fields as diverse as physics, economy, psychology, geography, biology and philosophy, as well as theories from a variety of different academic backgrounds as well. While I would never dream of claiming equal insight into all of these they have provided me with large amounts of relevant data as well as inspiration, scepticism and perspective that I have not previously encountered through my studies, and the interdisciplinary approach achieved through this combination of perspectives is both a reflection of the complex nature of sustainability as well as a requirement to solve the problems associated with it.

On a more philosophical level my approach is not guided by any specific theories of science that I adhere to, but probably reflect some connection to the early thoughts of Roy Bhaskar's transcendental realism and critical naturalism. By these I mean an approach that emphasises both the importance of internal mechanisms that may or may not be activated in order to observe the resulting outcomes, but that these mechanisms cannot necessarily be reduced to a set of axioms. Scientific discovery in a world of dynamic mechanisms is an ongoing process, and as such a scientific approach should be flexible enough to adjust to the changing nature of the objects of observation and analysis. Some mechanisms might not even reach activation and thus exist independently of our observations of their effects (or lack of). In relation to the study of sustainable mobility this means that while we might be to able to identify causal mechanisms in the natural sciences (such as burning x amount of fuel results in y amount of CO_2), that does not necessarily mean that causal mechanisms do not exist for phenomena just because they are not directly observable (e.g. within social science). In relation to transport planning in particular, it means that observations of behaviour or development trends cannot be attributed to a set of causal mechanics just because we observe these to take place, as they might be part of a chain of mechanics of which some are inactivated or counteracting each other. By changing the structural framework for society the resulting product of these mechanisms can thus also be changed. In my opinion this perspective is a required bridge between the natural and social sciences, both to understand the underlying mechanisms of society but also to actively change existing structures which are deemed undesirable.

Before moving on to the theoretical framework of this report I will present a short overview of the content of the report's individual chapters. The structure is fairly straightforward, with a theory chapter leading on to the analysis, followed up by a discussion.

1.7 The general structure of the report

Chapter 1

- Sustainable mobility: The chapter we have just passed is meant as a general introduction to the nature of the topic, the motivation behind studying it as well as an outline of the fundamental rationale behind the research approach I have used.

Chapter 2

- The foundations and framework: In this chapter I will elaborate on the concept of sustainable mobility as well as the scenario approach that will form the basis of the analysis. Furthermore, some of the relevant theoretical perspectives on which these scenarios are constructed will also be introduced.

Chapter 3

- Technology: The first of the three scenarios will be based on a technocratic solution approach to sustainable mobility. Focus is here on alternative and new conventional fuel types, but will also touch upon the concept of intelligent transport solutions.

Chapter 4

- Modal switch: The second of the three scenarios will focus on a change of the transport structure to encourage a shift from private car use to public transport, as well as possible barriers to succesfully implement such structural changes.

Chapter 5

- Demand management: The last of the three scenarios will focus on instruments of demand management in the transport sector, and how a possible reduction of transport volume can be achieved. through the use of land use planning and fiscal regulation.

Chapter 6

- Discussion: This chapter is meant to expand the discussion from considerations of only economy and ecology into a more general perspective. The societal consequences of the approaches used in the previous three chapters will be discussed as well as the concept of growth in general.

Chapter 7

- Conclusion: The final chapter attempts to string all the different parts of the report together to form a collective overview of the findings in the analysis and the following discussion. Comments on how these findings can be used in the field of planning then wrap up the report.

2 The foundations and framework

As was evident from the diagram of the report's structure this chapter is aimed at presenting the theoretical foundation of the report's content and research approach. This includes argumentation for the choice of constructing scenarios, and how these can be used as tools in studies of futures. In addition to this I will explain my definition of sustainable mobility as it is used in this report, as well as provide comments on the important characteristics of this definition. Finally, an overview of the fundamental principles that I consider to have been key elements in shaping the three scenarios of this report will be presented, as well as critique of the assumptions on which they are based where it has been found necessary.

2.1 Looking forward by moving backwards

Studying possible futures is no easy task if we are to produce more than a qualified guess on what is going to happen over the next decades. In order to evaluate the three different approaches I have chosen to build a scenario for each of them, with the purpose of describing the development of certain aspects of the future that the chosen approach will likely affect. Scenario building is used to create a perspective on the present that enables us to act today (Guttu, 1993), which in the case of sustainability means that it will allow us to plan ahead in order to avoid the paths to unsustainable futures. The aim is to create a set of scenarios that could fulfil the previously mentioned sustainability goals, and then identify the necessary decisions to be made in order to reach these. An evaluation of the societal desirability of these required decisions is then to uncover which of the scenarios it would make the most sense to focus on. This approach is different than traditional forecasting of current trends and more related to a backcasting analysis, and in this section I will explain how both scenarios and the backcasting approach will be used in this report.

One of the main reasons for using scenarios as an approach in this project is that any attempts at precision forecasts for such complex issues as transport and mobility issues are not likely to be very precise at all (Næss, 2006a). Even if they were it would require a great deal of resources put into such a project, only to reach a level of detail that is not at all required for a general analysis of development. If you throw a ball to someone you have an idea of what path it will take and where it will land. You don't need to know the precise trajectory it will travel, the amount of acceleration it will go through or the exact location of the landing spot to do that; you simply throw the ball. Calculating wind speed as well as the force and angle at which you need to throw the ball would be completely superfluous for such a task, as your target might have moved or the wind might have turned since you began your calculations. There is also a number of uncertainties that can affect how accurately you manage to throw the ball without doing these calculations, but general knowledge of gravity and friction coupled with past experience of how thrown objects behave is generally enough to get a good feeling of where your ball is going to end up. The idea is the same with future studies; there is little to gain from doing complex calculations of how the future will look 20, 50 or 100 years from now with the amount of uncertainty involved in such calculations, and the traditional forecasting methods are thus of little use in this case. Sadly, they are often employed for precisely these tasks, which lead to misinformation in the decision making process (Flyvbjerg et al., 2006).

2.1.1 Scenario principles

Working with scenarios is not a scientific method of predicting the future exactly the way it will turn out, but rather the opposite way around. It is meant to aid us in creating visions for desirable futures and the goals we need to set to reach them. It is thus a complex mix of creativity and believability that needs careful consideration in the build-up phase. Scenarios are often used in cases where we want to derail the current development because it has been deemed undesirable, and creativity is thus a requirement for producing alternative scenarios. However, too much creativity will end up in utopian ideals, and scenarios should thus also focus on futures we can believe in, so they are not dismissed as mere fantasy. Inspired by Guttu (1993) I will here list the main principles that my scenarios are based on in this report.

Scenarios are meant to broaden our horizon

Scenarios are neither prophecy nor prediction, and they should not be used to illustrate ideal goals for the future. They are primarily used to inspire us by presenting possible alternatives to the forecasted future in planning practise, and thus also alternatives to the current development trends. Unlike Guttu, who emphasises a need for qualitative different scenarios which are mutually exclusive, I will focus on scenarios with possible combinatorial benefits. However, I will split them up in pseudo-exclusive scenarios at first, to evaluate their individual effects on both the sustainability problems and their resulting societal consequences. A combination of factors from the different scenarios should still be considered, as it is highly unlikely that just a single set of approaches (e.g. those that form the basis of a separate scenario) will influence future development in the transport sector. Taking mutually exclusive benefits into account in such a combination is of course vital to the validity of it.

Scenarios should bridge our choices today with future consequences

This is basically the essence of scenario planning, as the purpose of it is to give us an idea about the connection between current policy and decision making and the results we can expect in years to come. Scenarios can thus serve as both a reminder of the possible consequences of our actions and as a driving force for alternative routes.

Credibility is more important than predictability

The idea here is that attempting to predict the future is a wrong premise for future studies. The most likely scenario is not necessarily the most desirable, and if the entire purpose of scenario constructing is to push for a change of direction in current trends, then predictability should not be the main objective. Perhaps part of the cause of a certain predicted future is the prediction itself, which tend to drive development and decision making in the predicted direction (Sager, 1991). If predictions show a tendency towards increased aerial transportation it might push politicians to construct bigger airports and increase funding for aviation related research, which in turn could increase capacity and lower prices for flying. This would increase aerial transportation affordability for consumers and thus transport volume would rise. This very simple example illustrates a big problem in traditional forecasting techniques, and the aim of scenario planning should be to reduce this effect instead of contribute to it. Producing credible scenarios that can help us decide on how to plan for the future is thus more important than predicting a future that we are actively shaping through the decisions we make based on those same predictions.

Scenario building is an iterative process

There is no straightforward approach to construct different scenarios and compare them, especially not with such complex concepts as sustainability. Consequences of scenario decisions and feedback mechanisms are important to consider, even more so when we are dealing with potentially irreversible changes. Scenarios should therefore if possible be modelled in discrete steps to allow a more systematic evaluation process. This might not be evident in the presentation in this report, but it surely has been so in the process of data collection and processing.

Scenarios should form a basis for decision making

As the intention is to explore alternatives to the current development, because that development is deemed undesirable, it is also important to consider what decisions will be required to reach a given scenario in order to contribute to the decision making process. The strategy we chose does not necessarily have to result in an exact match of any given scenario, the important part is that we are left with a set of options that will turn us in the direction of a more desirable development.

2.1.2 Backcasting

The approach to scenario building that I have so far described can be categorized as backcasting. According to Banister & Hickman the term was introduced in 1982 as *"a concern, not with what futures are likely to happen, but with how desirable futures can be attained. It is thus explicitly normative, involving working backwards from a particular desirable end-point to the present in order to determine the physical suitability of that future and what policy measures would be required to reach that point"* (Robinson, 1990). The desirable end-point in the sustainable mobility context of this report would be the one outlined in section 2.2, while the approach has gotten a small twist as I have already decided the three possible approaches for analysis. However, this does in no way rule out the option to use the scenarios analysis as a basis for policy recommendations. For this purpose backcasting seems to be a good approach, as it allows an option to define desirable futures and analyse both the expected consequences and required conditions for these futures to form, instead of just extrapolating current trends. However, it should be noted that unlike Robinson I have chosen to view backcasting as a general approach on a more fundamental level instead of a specific method. The reason for this is that the essence of backcasting seems to be the exploration of alternatives to current development, and a standardised method leaves less room for manoeuvring between such alternatives and trying out new approaches in general. Retaining freedom of action is essential to backcasting, and as such it seems illogical to stipulate rules for the creative process (Dreborg, 1996).

This is not to say that justification of the chosen method is irrelevant, as scientific methods would lose their credibility without it, but the nature of the problem usually determines which scientific disciplines are relevant to include in the study of it. Figure 3 gives a crude image of how the backcasting approach is intended to help us break the traditional forecasting prison by identifying the goals we want to achieve instead of trying to predict where we will end.

Three things should be noted when looking at figure 3. First, the current situation might not be environmentally sustainable as illustrated here, even if environmental impact is not increased. This is

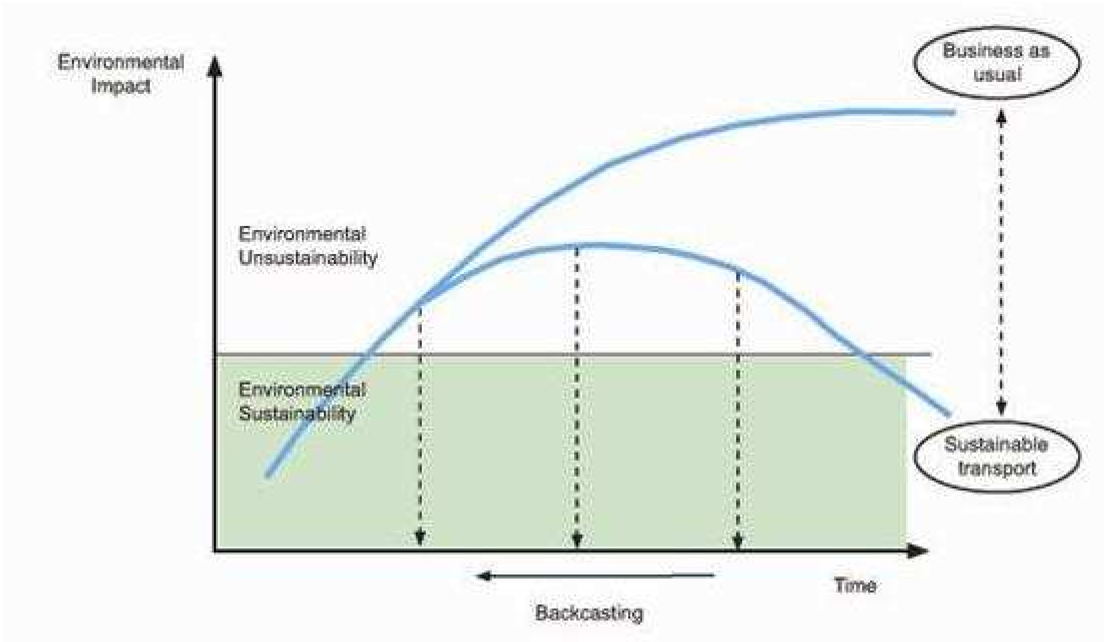

Figure 3: Conceptual framework of backcasting (Banister & Hickman, 2004).

particularly relevant in the case of climate change with its multiple positive feedback mechanisms[2]. Second, there is not one single path that leads to sustainable mobility, and it is thus important that multiple different approaches are examined. Third, the timeframe for such huge changes in development trends as illustrated here is usually quite long. It is hopefully possible for us to steer development onto a desirable course, but *"our perception of what is possible or reasonable may be a major obstacle to real change"* (Dreborg, 1996: 816). Backcasting can help reduce some of effects of this problem by allowing alternative approaches a bit of room to manoeuvre, and focusing on the required development to reach desirable outcomes instead of structuring society around forecasted demands. According to Dreborg backcasting should thus be considered when:

- Problems are complex (affecting many sectors of society).
- Marginal changes will not suffice (major changes are required).

[2] An example of such positive feedback mechanism would be the relation between heating and the albedo effect in arctic regions. As ice layers melt away due to global warming the albedo effect is reduced (in the polar regions in particular), and this causes further heating because of a reduced capability to reflect heat.

- Dominant trends are part of the problem (typically in forecasting).
- Externalities are part of the problem (cannot be solved by market forces).
- The time horizon is sufficiently large (allowing for deliberate choice and major changes).

In my opinion the problems related to sustainable mobility are very much in line with the above listed characteristics, making them an ideal case for a backcasting approach to be employed. Due to the nature of the backcasting approach my analysis will be focused more on discovering the potential for sustainable development along with the social consequences in each scenario rather than justifying any of them in particular. However, to discover anything about the potential of these scenarios a set of criteria must be formulated to serve as a basis for evaluation. In the next section I will therefore argue for my choice of criteria for sustainability and mobility as they have been used in this project.

2.2 Sustainable mobility

Sustainability in the transport sector seems to be both nowhere and everywhere at the same time. Both policy makers and planners agree that sustainable mobility is an important part of the overall sustainable development discourse, and attention towards the adverse effects on the environment and climate from transport is becoming more and more visible in both academic literature and government white papers (as well as in the public debate for that matter). However, increased awareness of the need to limit the harmful effects of transport have so far not led to any significant reductions in neither transport volume or emission levels. Investigating the reasons for this inconsistency would obviously be very relevant for project of this nature, albeit somewhat beyond the scope of the themes in this report. Instead I will direct my focus to the three different approaches towards achieving a sustainable mobility development mentioned in chapter 1. In the future it might turn out that they were neither the most optimal in addressing sustainability problems, or that they didn’t play any important roles in the development of the transport sector at all, but at the moment they are greatly influencing the discourse of sustainable mobility and as such their sustainability potential becomes of great interest.

Of the three approaches I just mentioned the technological and modal switch paths are by far the ones that is given the most attention by policy makers (technology in particular). One of the main reasons for this is the traditional coupling of economic growth and transport volume as was shown in section 1.3. If there is a causal link between transport activity and economic activity it would mean that a reduction approach is considered likely to not only result in a reduction of transport and its adverse effects, but also a reduction of economic growth potential (or possibly lead to negative growth). In a capitalist driven society a reduction of economic growth is in sharp contrast to the expansive nature of capitalism itself, and a hypothesis could be that instead of attempting a decoupling of GDP and transport volume efforts have mainly been directed towards a decoupling of transport volume and the environmental problems caused by it, in an attempt to avoid impacting economic growth. However, the idea that a reduction in transport volume would result in economic decline is based on the assumption that transport activity is a prerequisite for economic activity, and so far there has been little evidence to actually support such causality. In order to make any assessment as to whether a given approach has the potential of achieving sustainable mobility a definition of the term is needed. Inspired by Holden (2007) sustainable mobility will here be defined as a development which fulfils the following two characteristics:

Transport does not threaten long term ecological sustainability

Ecological sustainability is here analysed through a mix of energy consumption and CO_2 emissions, as these are often the indicators that require the least amount of calculation, as well as the ones where data is most likely to be readily available. Since I am primarily dependant on existing consumption and emissions data for my analysis this seems a necessary restriction on the ecological sustainability definition used here, but with full acknowledgement that this is not a fully adequate measure. Additional impact categories are included in some of the scenarios, either as supplemental data or in a discussion of adverse effects, and are thus not completely ignored in this report, but the main attention will be given to CO_2 emissions, which also better reflect the current political focus on ecological sustainability issues (whether justifiable or not).

Basic mobility needs are satisfied

While the primary focus of this project is on CO_2 emissions there is little use of sustainable mobility scenarios in which mobility demands are not adequately met. No quantifiable measures of travel distance are included for this characteristic; it should instead be seen as one of the main topics for discussion when considering the social consequences of achieving sustainable mobility, and will be addressed in the scenario chapters as well as the following discussion. This characteristic also includes social equity of mobility, i.e. any given approach should avoid promoting social exclusion. Basic mobility needs cannot be regarded only at an aggregate level as a sum of individual needs as this could favour an unfortunate polarization in which the highest income groups gain unrestricted mobility at the expense of the basic mobility needs of less resourceful groups.

Figure 4 illustrates how the above two characteristics can be used to define a more quantifiable measure for sustainable mobility. Inspired by the concept of a sustainable mobility area (SMA) described by Holden (2007) I have adopted a similar framework here, although merely for the purpose of explaining how the question of sustainability could be approached in greater detail than will be the case in this report. Gathering sufficient data for all three scenarios to be measured in relation to this definition is well beyond the scope of this study, but describing sustainability in more detail nonetheless seems necessary if a comparison of these scenarios is to make any sense.

In figure 4 I have chosen to let per capita energy consumption represent the first characteristic of sustainable mobility, which was transport's threat to ecological sustainability. Naturally this is a very reductionist representation since ecological sustainability is affected by a large number of other factors than energy consumption; an argument that can also be held against my previous decisions to focus on CO_2 emissions[3]. It should therefore be considered an example for the purpose of explaining the concept here and not understood as a finite measure for sustainability, although energy consumption does in fact tend to be a good indicator of other sustainability measures, which

[3] In addition to this it might be debated whether any per capita unit measure would make much sense in arguments of sustainability, since we do not have a per capita measure for the total capacity of earth's ecosystem, but a finite one. However, the illustrated limit in Figure 4 could be considered adjustable to adapt with population fluctuations, and in any case it is only meant as a crude representation of the concept.

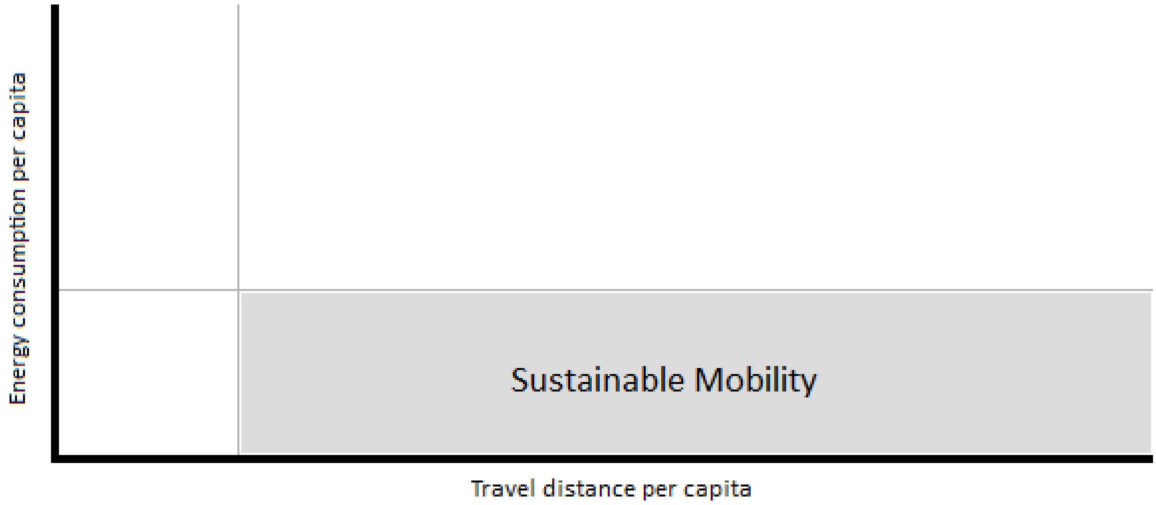

Figure 4: Sustainable mobility can be viewed as the area in which basic transport needs (vertical grey line) are fulfilled without exceeding a given threshold for energy consumption (horizontal grey line).

could also be used in its place. Alternative measures could be greenhouse gas emissions, ecological footprint or living planet index (WWF, 2004), although some of these can be hard to implement due to sample size or types of available data. In the case of energy consumption a threshold for per capita consumption can be adopted from existing studies, for example the works of the Brundtland commission, the International Energy Agency (IEA) or other similar organisations. For CO_2 the Danish government set a goal in 2002 of 25% reduction in 2030 compared to 1988 levels (Regeringen, 2002), but so far there has been an overall increase in emissions due to the massive increase in the transport sector, outweighing reductions in all other sectors combined (Energistyrelsen, 2008).

Travel distance is used as a measure to evaluate whether basic mobility needs are being met, but again this is only for illustrational purposes as travel distance could be replaced or complimented with a number of other measures for mobility. Average distance between workplace, home and common facilities used in everyday practise could be relevant additional data to include here, but for the sake of simplicity I chose travel distance as a single measure here. The relationship between GDP and transport demand could then be compared to establish a threshold for travel distance in order to fulfil basic mobility needs. As was the case with energy consumption as a representative for ecological sustainability there are also some obvious flaws in reducing mobility needs to a measure of mere travel distance, especially since part of a successful decoupling could result from a reduction in actual transport demand. This reduction is thus only made here for the sake of simplification.

There are of course many other factors which affect ecological sustainability and mobility needs than the one mentioned in this brief coverage, and I shall return to some of them after presenting the three scenarios in chapters 3 to 5. For the remaining part of this chapter I will focus on the theoretical foundations which have served as a basis for these scenarios.

2.3 Two types of decoupling

Returning to figure 1 (p. 11) we see that there are two possible ways of decoupling economic growth from environmental degradation in relation to sustainable mobility; either by decoupling economic and transport activity or by decoupling transport activity and environmental impact. The later type of decoupling have traditionally been given the most attention, usually in the shape of technological improvements in order to increase efficiency, and hereby increasing productivity without increasing environmental impact. Within the transport sector this usually means improving vehicle efficiency so they can operate the same distances but consume less fuel while doing so and thus ultimately lowering environmental impact. Promoting mass transport solutions is another way of increasing efficiency since it is usually beneficial to carry more passengers in the same vehicle, which would also allow for operating similar distances but with less fuel consumption.

The former of the two types of decoupling is aimed at a volume reduction, and while the two types of decoupling are not mutually exclusive they can be considered separate approaches to sustainable mobility. In relation to the transport sector it is clear that a volume reduction of transport would indeed also lead to reduced fuel consumption and thus a lower environmental impact. Other beneficial aspects of a volume reduction would include better traffic safety, reduced congestion and fewer resources for maintenance or expansion of the transport infrastructure network, and the environmental aspects of each type of decoupling should thus not be considered in isolation. The main obstacle for a reduction approach is of course to avoid a reduction of economic growth while reducing transport demand, and this is perhaps also why it is not often given much attention in the political arena. Ensuring a continuously expanding economy is usually the number one priority for governments worldwide, and any attempt at reducing a seemingly growth generating sector is bound to be met with some scepticism.

2.4 Ecological modernisation and the EKC

In this section I will cover some of the theoretical foundations on which the technology scenario is based. As I have mentioned earlier technological advance often gets the most attention when solutions to sustainable development are discussed, and while new technology and efficiency improvements are certainly important we should not let them cloud our judgement of other influential factors. As Urry puts it: *"It is important to resist a technology-first analysis since technologies do not just develop for endogenous reasons and nor do they then simply transform the economic and social landscape in their own image once they have developed."* (Urry, 2008: 262). As Urry reminds us, technology does not stand on its own, but is shaped by society just as society is shaped by technology. A social system must thus not consider technological advance solely as potential benefits, since new technology could lead to new consumption patterns or unintended harmful impacts related to their use, just as changes in other subsystems could impact technological development. Beck (1992) directly argues that any new technology is associated with new risks as well, and thus implementation of it needs to be critically scrutinized rather than embraced blindly. This is not to say that technology has nothing to offer society in terms of progress, but merely that considerations need to be made in regard to any potential adverse effects they might be associated with.

One particular theory has helped push technology to the top of the agenda lately when it comes to sustainability, namely that of ecological modernisation[4]. This theory basically challenges the idea that improvements in environmental protection are inimical to economic growth, which was the fundamental idea that dominated the aftermath of the environmental debate during the 1960s and 1970s (Barry & Paterson, 2003). Ecological modernisation is a great display of how political and economic institutions have responded to pressure from both environmental groups and the public at large in a way that does not conflict with industrial interests, and the basic perspective of the theory

[4] Other important theories to influence the discourse have been green capitalism and dematerialization, but these have a number of shortcomings as well, and have so far not managed to facilitate a successful decoupling. See Næss & Høyer (2009) for an overview of some of the critique.

is that while the most challenging environmental problems have been caused by modernisation, the solution to these problems lies in further modernisation, which suggests a techno-institutional fix for both present and future environmental problems.

Obviously ecological modernisation theory has a multitude of interpretations, but common to all of them are that their central claim "*converges on the notion that environmental protection is a precondition for economic growth, or is compatible with it*" (Barry & Paterson, 2003: 242). This claim is similar to the hypothesis of the Environmental Kuznets Curve (EKC), which has the fundamental premise that environmental quality will degrade up to a certain point, but afterwards it will improve with further economic growth when society passes a certain level of income. This has often been one of the dominating rationales behind policymaking to increase sustainability, and has been evident in government programmes from a range of European countries including Sweden, Holland, Germany and England (ibid.). There is a burgeoning amount of literature on EKC, both from advocates and critics, but the general idea is nicely illustrated in figure 5. Looking at this figure it becomes apparent that for societies which have reached or are close to reaching the peak of environmental degradation it becomes increasingly important to continue economic growth, as it is a precondition for reaching the level of environmental protection that facilitates a declining degradation.

Looking at the above mentioned characteristics it would seem that EKC could be used to promote any of the three strategies that are used for the scenarios of this report, as long as economic growth is ensured. Traditionally EKC has however been closely related to theories of ecological modernisation as mentioned earlier. This is likely to be explained with the justification of a technocratic solution approach to environmental problems that it enables, which have been the dominant perspective in many western societies and still is in many today (Barry & Paterson, 2003; Hillman, 2004).

A problematic issue with the ecological modernisation approach is that the hypothesis it primarily builds upon (EKC) has yet to be backed up by any substantial empirical data set. On the one hand development of certain pollutants has shown a trend that looks somewhat close to what the EKC

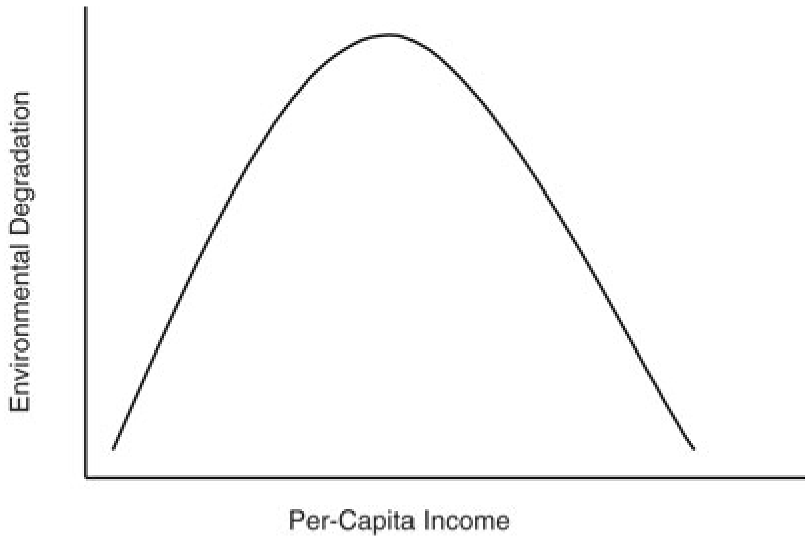

Figure 5: Basic outline of EKC (Hayward, 2005).

describes (Hayward, 2005), but on the other hand it has proved particularly unsuccessful in explaining the development of CO_2 emissions from the transport sector (Haukioja et al., 2001; Tapio, 2005). In relation to sustainable mobility this obviously constitutes a significant problem for any policy making and planning, that tend to focus primarily on technological solutions, which currently to be the dominant trend. This problem will be the focus of the first scenario, where the potential gains from new fuel technology will be addressed.

2.5 Public transportation

The modal switch approach is another addition to the sustainable mobility debate, which has also gotten quite a bit of attention lately. In a Danish context the recently published government investment plan for infrastructure projects has been followed by public debate regarding the (lack of) attention towards the role of public transport within it, and how to obtain such a modal switch. The general idea of a modal switch is to make the users of the infrastructure switch from one type of transport to another. In the case of sustainable mobility this especially implies from cars to 'greener' modes of transport such as busses or rail based transportation, but it can also be motivated by problems such as congestion in urban regions. The factors that are usually brought up as influential to users' choice of transport mode are things as convenience, price and travel time, while the main benefits from the modal switch in a sustainability perspective is an expected reduction in emission of pollutants per passenger kilometres travelled (PKT), or time savings in the case of congestion.

This reduction is expected due to the larger passenger capacity of busses, trains, trams, etc. compared to that of a car. The car is traditionally recognised as a convenient mean of transportation, which offers increased mobility and travel comfort to its user, but as of lately it is also increasingly recognised as the cause of severe pollution, traffic danger and fuel inefficiency (Harman, 2004). The pros and cons of the car present a classic example of a tragedy of the commons, in which the increased mobility of the user comes at a cost that is to be covered by society at large. While the terminology 'tragedy of the commons' was first introduced by Hardin (1968), the problem of exploitation in matters of private vs. common interests have been described as far back as ancient Greece[5], and since then it has also been a central problem of much political philosophy. For a wide range of related problems the most common solution has been government regulation, and while some degree of regulation has also been introduced for transportation, the modal switch approach traditionally relies more on encouragement than enforcement. But, as Hardin also claimed when introducing the terminology, when a problem can be classified as a tragedy of the commons it represents of case where freedom must necessarily be restricted to some degree. For this he used the example of a field used for grazing on which a group of herders kept their livestock. Each individual herder will gain one extra unit of production for himself by adding a piece of livestock to the field, while the resulting costs of overgrazing are shared by the entire group:

> "*Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another.... But this is the conclusion reached by each and every rational herdsman sharing a commons. Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit--in a world that is limited. Ruin is the*

[5] Aristotle expressed the problem as follows: "*For that which is common to the greatest number has the least care bestowed upon it. Everyone thinks chiefly of his own, hardly at all of the common interest; and only when he is himself concerned as an individual. For besides other considerations, everybody is more inclined to neglect the duty which he expects another to fulfill*" (Jowett, 1885).

destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all."

Hardin (1968: 1244)

Whether a modal switch takes place by stick or carrot is however not what interests me the most in relation to the scenarios in this project. The resulting impact on the environment if a desired modal switch is achieved is what is in focus here, as public transport is not a sustainable solution per definition of being public; it is merely less polluting than private cars in most cases from utilising its higher passenger capacity. The largest Danish train operating company DSB brands itself as a green alternative, but will using bus and train instead of cars make transport sustainable? That is the question I want to answer with the second scenario.

2.6 Land use planning

Land-use planning suggests that the physical environment in which transport occurs has an influence on the total transport demand and that the physical urban structure should thus be designed in order to reach a more sustainable scenario by minimising the need for transportation. For several decades the relationship between urban structure and transport demand have been studied, but this has yet to result in consensus among planners about any causal mechanisms in this relationship. Some researchers have argued that physical structure is indeed an influential variable that affects transport demand in a significant way (Banister et al., 1997; Næss, 2009; Brownstone & Golob, 2009), while others claim that individual travel preferences prevent any causal mechanisms from being identified (Krizek, 2003; Cao et al., 2007). There does however seem to be some consensus that people living in denser populated urban areas tend to travel less than people living in less densely populated areas, which usually means that people residing in the centre of a city travel less than people residing in the peripheral area (Krizek, 2003; Næss & Jensen, 2005). This is also coupled with a reduced level of car ownership in the more densely populated centre areas as well as increased levels of public transport usage.

Some of the factors that could exercise influence on transport demand are distance between home and workplace, public transport access, location of spare-time activities, shopping options and location of friends and family. While these may not be mono-causal factors for transport demand they must at least be expected to play a role in the decision making on transport choices for most people on a day-to-day basis. I will regard them as INUS-conditions[6], a term first introduced by philosopher John Mackie in 1965 "*in the context of his work to provide a logical analysis of the relation of causality in terms of necessary and sufficient conditions*" (Horsten & Weber, 2005). According to Næss & Jensen (2005) an INUS-condition denotes a necessary condition for a result that is however not sufficient. If C is a condition and there exists conditions A and B so that

$$\big((C \wedge A) \vee (C \wedge B)\big) \leftrightarrow D$$

then C is an INUS-condition of D. If we look at some of the structural factors mentioned in the beginning of this paragraph we could let the distance between home and work (Aalborg University in my case) be a condition for driving the x kilometres it takes me to get there in the morning. It wouldn't be a mono-causal condition though, as I am unlikely to make that trip on weekends or after I finish my studies, but it is still a necessary condition as I would generally be making a different trip if I lived somewhere else no matter what the other conditions might be.

How areas of residence, commerce, industry, etc are located in relation to each other and how they are shaped, formed and used are all part of the urban structural frame, which will stimulate some types of transport activity in a higher degree than others. Some types of transport related activities are more directly influenced by urban form than others however, with the 'mandatory' trips (work, shopping, kindergarten, etc.) being the most likely candidates for such influences, as they can be expected to be part of a daily routine. 'Optional' trips (spare time activities, leisure travel, visiting friends/family, etc.) are less likely to be tied up on daily routines, and as such could prove harder to influence through the physical structure of urban regions. Although some spare time activities are

[6] INUS: **I**nsufficient but **N**onredundant part of a condition, which is itself **U**nnecessary but exclusively **S**ufficient in the circumstances.

located near the city centre and could perhaps be expected to mirror the effects of more frequently used facilities due to location, there is also a large number of people involved in various sports activities in their spare time that might as well be placed outside or on the outskirts of urban areas (football and golf come to mind in a Danish context at least). The lower degree of routine based behaviour associated with these types of activities could possibly mean that the transport demand they generate is more random than for mandatory trips. In the third scenario I will therefore be focusing primarily on everyday travel behaviour.

2.7 Transport pricing

In most of the western world average incomes have reached a level that has allowed for a fairly low ratio of citizens per car; a trend that has only been increasing over the past decades. This has led to an increasing amount of attention to the actual cost of transport in this period as transport pricing seems to be one of the few regulatory mechanisms with a very direct impact on transport demand. Most major European cities have experienced a mounting fleet of cars, longer trips and fewer passengers per car in recent years, which have increased emissions levels accordingly. Furthermore, the car's increased share of transport have led to rising congestion levels as well, which further increases the emission problems due to stop-and-go traffic. In an attempt to keep traffic at a reasonable level some politicians have started using different fiscal instruments to reduce traffic demand, such as green taxes or various types of road pricing. The latter has already been implemented in many cities of northern Europe including London, Stockholm, Oslo, Bergen and Trondheim (Rich & Nielsen, 2007), and while demand management has not always been the rationale behind implementing these systems they have resulted in a reduced transport demand. Another type of fiscal regulation instrument can be applied through adjusting charging and locations of parking facilities. Car user's visiting the city centre prefer street parking to a much higher degree than designated garages, which often leads to cars circling blocks for large amounts of time in order to find a suitable parking spot near the owner's destination (Gagliano, 2008). This increases both congestion and emission levels in downtown areas and could be solved partly by increasing the economic benefit of parking in garages instead of at street level.

In a Danish context the current government has been very reluctant to discuss transport pricing as an instrument of regulating transport demand, and has instead pursued a 'predict & provide' approach to congestion issues through a continuous expansion of the road network. Traffic spokesman Kristian Pihl Lorentzen of the government party Venstre stated that the party maintains a position of saying "*no to a guardian-like behavioural regulation as toll and high parking taxes*", a view that was supported by political spokeswoman Henriette Kjær of the government party Konservative (Information, 2007a). The 2008 report from the Danish Infrastructure Commission (Infrastrukturkommissionen, 2008), which was supposed to serve as a general guideline of where to focus investments and efforts for infrastructure, was under severe criticism for not including road pricing and other types of fiscal instruments for reducing transport demand. The critique spanned from such diverse actors as political opposition parties, researchers from different Danish universities, the minister of climate and members of the commission itself (Væstenbæk et al., 2008). The government has since gotten a more positive attitude towards fiscal regulation instruments, but still chose to exclude toll charges around Copenhagen from the 2008 investment plan in the last stages of the negotiations (DR, 2008). It seems unlikely that road pricing of some sort will not be implemented in Denmark within a decade or two, and I have thus included it in the third scenario as an instrument of demand management.

3 Technology

The first of the three scenarios is focused towards the impact that technological advancements can be expected to have on the potential for decoupling economic growth and environmental impacts from transport. There are of course many sectors in which technology related improvements will affect these impacts, but for this study I have chosen to focus on two central focal points for policy makers: fuel efficiency and ITS. The main analysis will be directed towards identifying reduction potentials of what I consider the most relevant alternative and new conventional fuel types, and while the impact of ITS will also be discussed in this chapter it will be a brief overview compared to the fuel analysis.

3.1 Efficiency through technology

The first scenario is based on an approach that focuses heavily on technological improvements in the area of fuel efficiency. Fuel efficiency relates both to new conventional and alternative technologies, and such solutions have long been favoured in politics This is especially true in a European context (Nykvist & Whitmarsh, 2008), meaning that this scenario is probably the most likely to take place if current trends continue unaltered. Important questions need to be answered are if these technologies can make transport sustainable and how they can be implemented on a large scale. While none of these questions are simple to answer, the first seems more straightforward than the second, since it is basically just a matter of optimization in the energy chain. The second question is of a much more complex nature as it is entangled in the interests of manufacturers, consumers and politicians alike, which can serve as huge barriers of implementation even though an optimal solution has been identified from a sustainability perspective. In this chapter I will look at answers to both questions of identification and implementation of sustainable mobility technologies.

In regard to fuel efficiency I will analyse how different types of fuel perform in comparison to each other using a Well-to-Wheel analysis (WTW) as well as an analysis of their ecological footprint (EF). Much of the inspiration and framework of the analysis comes from Holden (2007), who has done an extensive analysis of the sustainability potential for a wide range of fuel types. I will try to include both conventional and alternative fuel technologies as well as hybrid solutions in order to get a broad overview of what is actually possible to achieve in terms of sustainability, but also how dramatic changes this would require for the current system in terms of production, distribution and stakeholders.

Alternatives to the traditional fossil fuels used in cars and other transport systems have been discussed since the 1960s (Holden, 2007), and while they are getting massive attention both in academia, media and politics today, traditional fossil fuels are still very dominant in the transport sector. Originally such endeavours were not related to sustainability but stemmed from a desire to ensure national security for fuel supplies. However, with the Club of Rome's 1972 publication *The Limits to Growth* there was a highlighting of absolute limits in relation to non-renewable natural resources, which was only reinforced by the following oil crisis in the years to come and culminated with the nuclear power discussion. Since then we have seen the emergence of a variety of new energy sources such as solar power, wind turbines, wave catchers, bio fuel and heat pumps that are all more sustainable than fossil fuels simply due to them being renewable. Many of these have however proved difficult to transfer into vehicle units due to the high demand for mobility, reliability and endurance that energy sources for use in cars and similar transport systems need to have. This is one of the reasons why transport has remained "*the societal sector most fundamentally dependant on fossil-based energy. In every country – rich or poor – transport is almost entirely dependent on it*" (Holden, 2007: 84).

As research within the field of transport and fuels has been very extensive one might expect this unsustainable coupling to show a trend of decline, but in fact the reality is very different as energy use for transport has continued to grow for both passenger and freight transport. If fuel efficiency is expected to make transport more sustainable it is thus of vital importance that new solutions both provide radical efficiency improvements to break the long curve of growth in energy consumption as well as compensate for future increases in transport demand. At the same time it is equally important that solutions are valid alternatives that can serve as long-term replacements for the existing fossil-based energy systems currently in use, as they will otherwise have little effect in making transport more sustainable. Path dependency is one of the main barriers to replacing existing technology for fuel systems as it is now only the engine that needs to be replaced, but the entire supply change of extraction, production and distribution that needs to be changed. Needless to say this is no simple task, and it is often met with great resistance from those actors who are removed or gain a reduced share of the value added chain. Investing in the wrong technology means we are likely stuck with it for some time and it should thus offer a sizable reduction potential.

For the fuel efficiency analysis I will focus on data from experiences with private cars since this is simply where the largest amount of data is available. Private car use also account for a majority of the fuel use and CO_2 emissions in the transport sector, meaning that any kind of technological approach to sustainable mobility solutions would have to offer improvements in this area. In regards to what a reasonable timeframe for fuel technology should be, it needs to be long enough that alternative technologies can mature enough to compete on somewhat even terms with the conventional types, but at the same time it needs to be short enough to allow for a discussion of technologies that are implementable in a foreseeable future. A timeframe of 10-15 years thus seems to both allow for a ripening process as well as being limited enough that we can make some reasonable assumptions about what we can expect from technological advance over this period.

3.2 What fuels are expected to be sustainable?

As stated earlier in this report I will focus primarily on the potential reduction of CO_2 emissions or CO_2 equivalent emissions. This does not mean that I completely ignore other aspects of sustainability, but as CO_2 reductions are the core of most sustainability discussions of contemporary transport policy it seems like a natural place to start, and I shall return to other aspects of sustainability in a later discussion of environmental impact categories for the various fuels. The data and fuel types selected for analysis and presented in this section are largely based on Holden (2007), who have done a great job of comparing the most relevant fuel types for the same timeframe that I used in this report. Common to the fuels used here are that their feedstocks are easily available in Europe, the technologies are expected to be available in the given timeframe (commercial by 2010, broadly applied by 2020) and they offer potentials for reductions of environmental impact compared to conventional petrol/diesel-based fuels. I have not adopted the full list of fuels used by Holden, but rather tried to single out a few reference fuels, which describe the potential reductions of environmental impact for various categories of fuels. The seven fuels[7] I have chosen to include for comparison in this report as well as the power trains[8] in which they are used are listed here:

1) **Petrol** used in a conventional internal combustion engine. This is my reference fuel since most Danish cars today are petrol driven, and although diesel cars have become increasingly popular during the last decade they still only account for 16% of the total Danish car fleet (Statistikbanken, 2008). Although 2010 is only one year ahead I have based the reference fuel on expected 2010 efficiency instead of actual current values to avoid different timeframes for the fuel types.

[7] CNG = compressed natural gas, CGH = compressed gaseous hydrogen, LH = liquefied hydrogen, HPE = hydropower electricity

[8] ICE = internal combustion engine, HEV = hybrid electric vehicle (ICE + electric motor), FC = fuel cell (technically a hybrid of FC + electric motor), BEV = battery electric vehicle

2) **Diesel** used in a hybrid electric vehicle. Hybrid cars have been commercially available for about 12 years now with the introduction of the Toyota Prius in 1997. I have however chosen to exclude petrol hybrids as they score worse than their diesel counterparts in energy usage, CO_2 equivalent emissions and local pollutants and thus do not seem a natural choice for a sustainability approach.

3) **Compressed Natural Gas** used in a hybrid power train. Natural gas has been discussed as a possible substitute for petrol/diesel-based fuels. As was also the case of diesel I will not include results for use in an internal combustion engine due to the inferior performance compared to the hybrid counterpart, and development seems to dictate a move from conventional internal combustion engine to a hybrid internal combustion engine coupled with an electric motor for most manufacturers.

4) **Compressed Gaseous Hydrogen** used in a fuel cell. Natural gas can also be converted to hydrogen instead and then used in a fuel cell. However, the assumed energy efficiency of fuel cells differ quite a bit when consulting different sources, with some researchers estimating efficiency in the mid 20s while car manufacturers claim it to be as high as 40%. For this study I will thus be using an intermediate efficiency estimate of fuel cells.

5) **Liquefied Hydrogen** used in a fuel cell. This fuel type has mainly been included to show that the production process of fuels has a huge impact on their potential for achieving more sustainable mobility, as hydrogen used in liquid form has a much higher environmental impact than when used in gaseous form. It is thus not only important to choose the right fuel type but also the power train used for any engine designed to use that fuel.

6) **Hydropower Electricity** used in a battery electric vehicle. This fuel is a bit different since a pure battery electric vehicle has some performance limitations compared to conventional cars, but the tradeoffs are remarkable reductions in pollution which is illustrated by complete CO_2-neutrality (see figure 6 and table 2 on the following pages). This rather spectacular result obviously depends on the power supply for the electricity as will be discussed later in this chapter.

7) **Methanol** used in a conventional internal combustion engine. Methanol is included as a representative for the biomass fuels, and results are from use in an internal combustion engine instead of a fuel cell as they do not differ much, although it should be mentioned that local pollutants are cut in half when going from internal combustion engine to a fuel cell with

methanol (local pollutants are however already reduced by a factor 10 for methanol used in an internal combustion engine compared to current petrol cars). Methanol is chosen over ethanol due to its much lower flammability which results in better safety as well as its ability to be produced from a broader variety of biomass materials, which would result in lower prices if it were to be the future fuel to use for transport (Domestic Fuel, 2006).

Having selected seven different fuels I will start with a comparison of their expected CO_2 equivalent emissions, for which data is based on various Well-To-Wheel (WTW) studies (Ecotraffic, 2001; General Motors, 2001; General Motors, 2002; Holden, 2007; Weiss et al., 2000). The overall aim of a WTW analysis is to evaluate how different types of fuels compare in regard to environmental consequences. These types of analysis are often split into two parts called Well-To-Tank (WTT) and Tank-To-Wheel (TTW), and as their names imply they focus on the environmental consequences of fuel production and fuel usage respectively. It should be noted that a complete WTW analysis does not account for energy consumption of emissions generated from manufacture of vehicles, infrastructure or distribution systems. It only includes the actual feedstock production and transport as well as the fuel production, distribution and end use. The results for the chosen fuel types in this report are shown in figure 6.

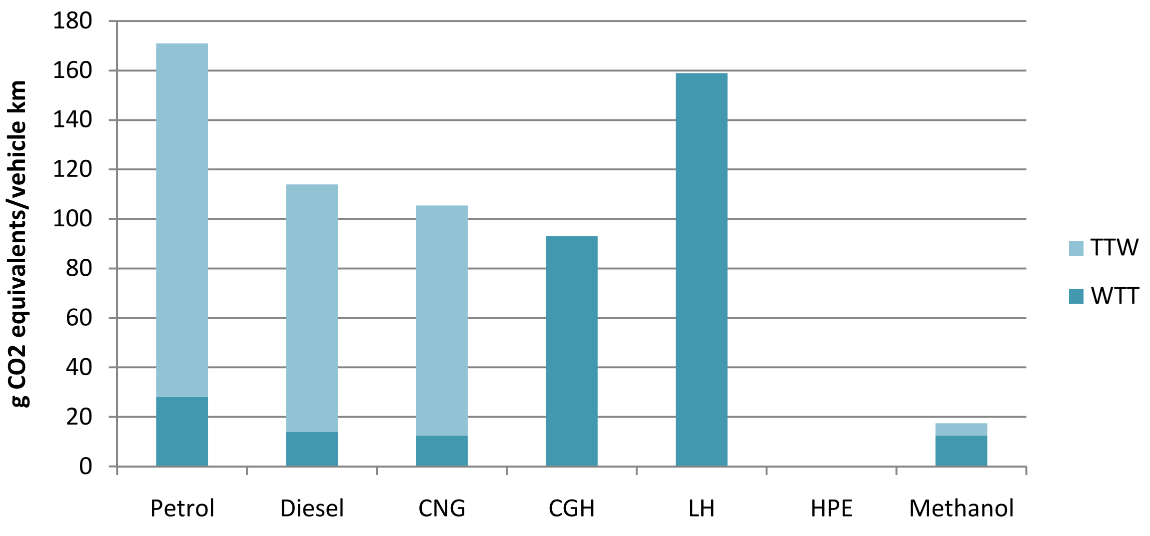

Figure 6: Well-To-Wheel CO_2 equivalent emissions for a passenger car under mixed driving conditions.

Looking at just the CO_2 equivalent emissions we can make at least three obvious conclusions from figure 6. First, it seems clear that the six alternatives to the reference fuel all offer some reduction in greenhouse gas (GHG) emissions as all of them have lower emission levels than the reference fuel (petrol). Second, it can be seen that the various fuel types selected for comparison either have dominant WTT emissions or dominant TTW emissions, with a clear trend for fossil fuels to have low emissions levels at the production site but very high on actual usage (vice versa for alternative fuels). Third, the potential reduction in CO_2 equivalent emissions differs greatly between the various fuel types, which is further illustrated by table 2.

Fuel type	Diesel	CNG	CGH	LH	HPE	Methanol
Difference	-33.3%	-38.3%	-45.6%	-7%	-100%	-89.8%

Table 2: Difference in CO_2 equivalent emissions compared to conventional petrol.

Looking at table 2 it seems that the future of sustainable mobility lies with battery driven cars or biomass production for fuelling conventional combustion engines. Both fuel types offer incredible reductions in CO_2 equivalent emissions and both are based on technologies which are expected to become commercially available in the near future. Liquefied hydrogen seems to be the clear loser in this comparison, and while natural gas and diesel hybrids offer substantial reductions they simply pale in comparison with hydropower electricity and methanol. However, so far I have only presented the potential reduction for GHG emissions for the various fuel types, and while it is certainly the dominant focus of most politicians in contemporary transport policy there are also other important environmental effects to consider, that could affect the possibility of achieving sustainability by using these fuels for future transport solutions. In the next section I shall present further discussion on some of the other environmental aspects that are relevant in relation to the fuel types selected here.

3.3 GHG reduction ≠ sustainable development

If CO_2 equivalents are not an adequate measure of sustainability then what do we need to throw into the mix to gain a better understanding of the adverse effects of the different fuel types? Some candidates for further WTW analyses could be energy usage, NO_x emissions and ecological footprint,

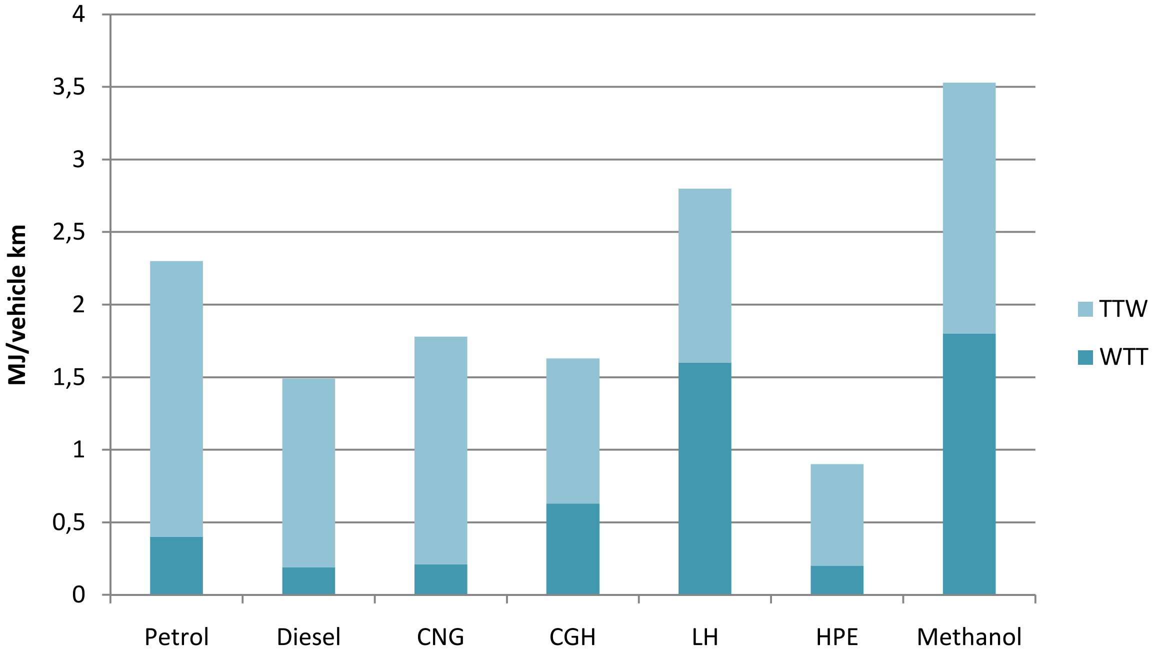

Figure 7: Well-To-Wheel energy consumption for a passenger car under mixed driving conditions.

but outside the WTW analyses we also find a number of relevant factors to consider such as performance, weight and price. If we start by looking at the energy consumption (figure 7) we see a few changes in the efficiency of the various fuels compared to that of their emissions of GHG. Diesel, compressed natural gas and compressed gaseous hydrogen are still performing better than petrol and are also in roughly the same efficiency range (as was the case in figure 6), but diesel is now the best performer of the three. Liquefied hydrogen and especially methanol are consuming even more energy than the reference fuel petrol, which in both cases is due to very high energy consumption in the WTT energy chain compared to the other fuel types. Production of hydrogen from natural gas requires large amounts of energy, especially so for liquefied hydrogen, which also incurs increased cost and complexity for manufacturers due to the need for on-board reforming. This also hinders vehicle performance and thus causes most manufacturers to focus R&D on compressed gaseous hydrogen (Risø, 2004). Methanol from biomass requires large amounts of energy as well, since two units of biomass are needed for every one unit of methanol produced (similar values for ethanol production) (Holden, 2007).

Fuel type	Diesel	CNG	CGH	LH	HPE	Methanol
Difference	-35.2%	-22.6%	-29.1%	+21.7%	-60.9%	+53.5%

Table 3: Difference in energy consumption compared to conventional petrol.

Looking at table 3 we see that apart from diesel used in a hybrid setup all other fuels have less energy savings than they have GHG savings compared to conventional petrol use. Liquefied hydrogen and methanol actually have considerable increases and are worse alternatives than conventional petrol in terms of energy consumption. Of the two fuel types that offered large reductions for GHG only hydropower electricity manage to also cut energy consumption, and while not as impressive as a complete reduction of adverse effects as we saw with GHG in table 2 it still offers to reduce energy consumption to nearly a third of conventional petrol's consumption level. The data from figure 7 is particularly interesting as it shows that new conventional as well as alternative fuel types all demand high amounts of energy that has to come from somewhere. This energy consumption cannot be neglected as increasing transport levels will mean increasing energy demands, even if we manage to decouple transport from other adverse effects it is causing (such as GHG emissions). This puts an increasing demand on these energy supplies to become more sustainable if transport is to become sustainable, which in turn will mean competition with other industries, who also hope to reduce their environmental impacts through the use of sustainable energy supplies. Unless a technological revolution suddenly makes sustainable energy readily available at a reasonable cost and in huge volume, it seems slightly optimistic to expect huge sustainability gains for all sectors through the use of such energy supplies.

I will not be including figures for NO_x emissions here as they are very close to what we could expect, with high levels for petrol/diesel, medium-low for gas/methanol and very low for hydrogen/electricity. I will instead move on to the results of the ecological footprint analysis based on Chambers et al. (2000) and Holden (2007), which can be viewed in figure 8 and table 4. It should be noted that ecological footprint is not traditionally done as a WTW analysis, but instead split between the areas set aside for production of fuel (production site and waste disposal) and actual fuel use (area required to assimilate pollutants). However, as this separation mirrors that of the WTT and TTW parts of a WTW analysis I have chosen to use the same taxonomy here.

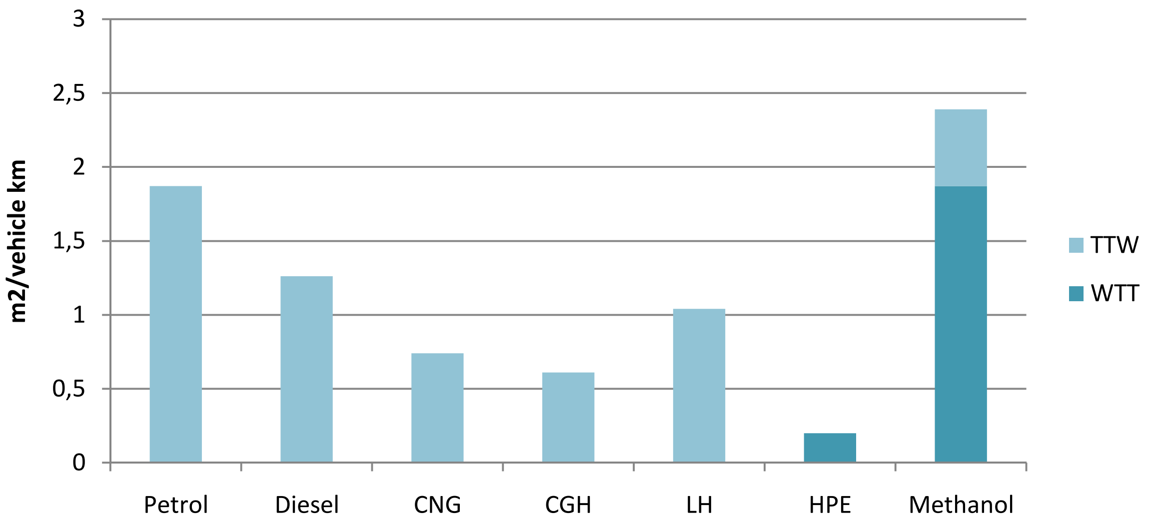

Figure 8: Well-To-Wheel ecological footprint of fuels for a passenger car under mixed driving conditions.

Fuel type	Diesel	CNG	CGH	LH	HPE	Methanol
Difference	-32.6%	-60.4%	-67.4%	-44.4%	-89.3%	+27.8%

Table 4: Difference in ecological footprint compared to conventional petrol.

Starting with figure 8 we see that most of the selected fuel types perform better than petrol in terms of ecological footprint, with only methanol scoring much higher due to the high energy production required. Hydropower electricity is also a clear winner once again and requires only about a tenth of the area that petrol needs in order to assimilate its main pollutants and prevent accumulation in the atmosphere or critical pollutant loads in soil deposits. Diesel was able to compete with natural gas and gaseous hydrogen in regards to GHG and energy consumption, but here we see that the high NO_x emissions from diesel make it suffer in the ecological footprint comparison.

What has hopefully become clear from figures 6-8 and tables 1-3 is that sustainability is hard to measure on a simple scale, as benefits in one environmental category usually leads to shortcomings in another. Although reductions are certainly possible compared to conventional petrol fuel there was only one fuel type that managed to offer a significant improvement over diesel used in hybrid cars, which are already commercially available today. The fuel types that were close to diesel are fossil-based as well, and there seems little long-term benefit in focusing on these based on the results presented here. The biomass representative methanol did offer large reductions in GHG emissions, but did so with a trade-off of both higher energy consumption and a very high ecological footprint. In light of the recent discussions both in media, politics and academia over the impact of bio-fuel on world food production this does not seem like the optimal alternative to petrol either. Furthermore, some researchers argue that biomass fuels are often unevenly distributed in terms of sites of production and consumption. This could lead to increased transport costs in regard to distribution and would likely also be coupled with some of the same problems of resource scarcity that we are witnessing over oil today, with armed conflicts and huge price fluctuations as a result. At the recent Beyond Kyoto conference in Århus (Denmark) this year, Bernd Möller (2009) argued that in Denmark we will have utilised between 50-80% of the total biomass resources by 2030 just with the current share of biomass fuels in the energy chain. This does not leave much room for further utilisation of biomass resources for transport as energy production in general are also looking towards more biomass production.

All of the above means that electricity-based fuel remains the only viable alternative for achieving sustainable mobility through technological improvements to energy efficiency, but since it offered amazing reduction-potential in all of the categories above that might not be a problem after all. Pure electric cars have long been available on the market, and the 2008 peak in oil price along with the ongoing financial crisis has resulted in increased focus on battery electric vehicles from the R&D-labs of several large car manufacturers. After all, if the technology is readily available and the environmental impact is minimal then what do we have to worry about? Well, as mentioned earlier the WTW analysis used in this report have only covered a finite set of environmental aspects, and the hydropower electricity used in the fuel comparison might have other environmental impacts than GHG emissions, energy use or ecological footprint. Land-use conflicts are sure to arise if hydropower is expected to fuel to world's car fleet, as a hydropower plant already now causes great disruption to the environment in which it is placed. Loss of taxonomic richness, reduction of biomass size for various species and absence of coarse fish are just some of the adverse effects that construction of a hydropower plant have been reported to cause (Cushman, 1985; Jalon et al., 1994), and even if these effects were to be ignored it is unlikely that all battery electric vehicles would be powered by hydropower due to supply limitations. If fossil fuels were to be used in the production of electricity instead of hydropower it would result in large increases in GHG emissions and energy consumption compared to the data presented in figure 6. In addition to this, battery electric vehicles currently have severe performance limitations compared to conventional cars in terms of driving range, speed and acceleration which could discourage car users to switch.

Overall it should be clear that the 'best fuel type' depends very much on the environmental category you choose to measure. Each fuel type is associated with a range of pros and cons in regard to environmental impacts and there is no clear way of singling out a 'best' fuel for achieving sustainable mobility. That being said, it seems that electric cars does indeed offer remarkable reductions in environmental impacts if the production of electricity can be done in a more sustainable matter and the performance reductions are ignored.

3.4 Inherent sustainability problems

As I have argued earlier in this report the dominant approach has traditionally been that of technological advance, but so far the efficiency of newer vehicles have not resulted in an overall reduction of CO_2 emissions which is illustrated in figure 9. Note that the values for total fuel consumption are based on fuel consumption levels from certification test, which are often producing very favourable results compared to actual fuel consumption from everyday use. This means that the increase in total fuel consumption is likely to be higher than what is displayed here.

One of the reasons for the gap between efficiency and total consumption has been an increase in overall transport volume. Judging from figure 1 (p. 11) the increase has been roughly 10% in the period from 1995 to 2002 for Denmark. Apparently the increased distance travelled has more than offset the efficiency gains from better engine technology. However, transport volume increases alone do not explain the whole story behind the discrepancy between total fuel consumption and per vehicle consumption. Increasing safety requirements and various features in new cars have increased their weight compared to older models, which reduces the efficiency gains from better engine technology. At the same time there has been a steady increase in engine performance, which further reduces efficiency gains. A standard 2004 Volkswagen Passat engine could muster 125 kW and 170

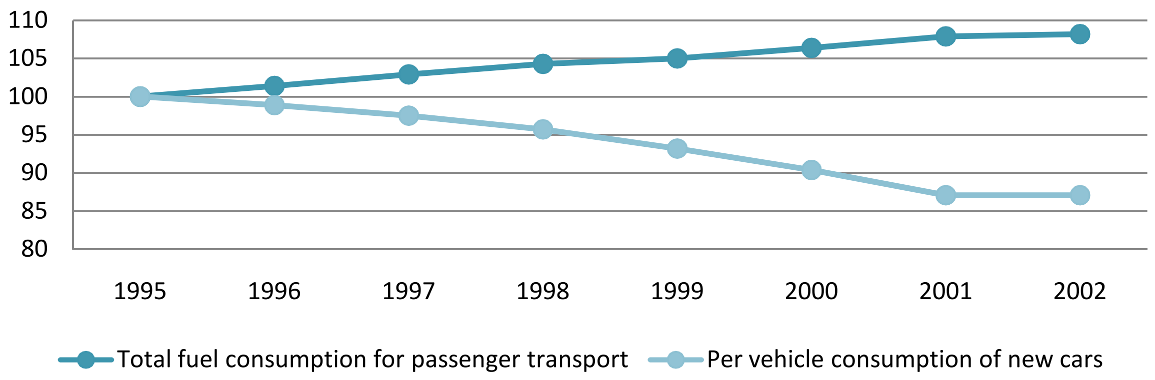

Figure 9: Total fuel consumption for passenger transport versus energy efficiency of new cars sold in EU15. Replicated from Holden (2007).

HP running at 5900 RPM while a 2009 model increases this to around 150 kW and 200 HP at only 5100 RPM. In its current design the model has more than doubled its weight since the early 1990s (Autoguide, 2009), and increasing safety standards continue to add weight to new vehicle models. Increased weight and performance means that per vehicle consumption in figure 9 is higher than it could have been. Furthermore, in Denmark the high level of taxation on cars mean that compared to EU15 we have a relatively old car fleet when comparing with countries of similar GDP/capita, and with recent changes to environmental zones in Germany we are seeing a large influx of older German cars, which are no longer allowed into cities south of the border (Politiken, 2009).

What does this mean for sustainable mobility then? For Denmark, an aging car fleet, that does not look to be upgraded significantly in the near future, obviously constitutes a bit of a problem for the government goals for CO_2 reduction, since older cars in general have higher emissions than new ones. A new taxation system is intended to make newer and more fuel efficient cars attractive to the Danes, but such a system has already been in place since 1997 and has yet to see any documented impact on actual car purchases. The Danish Ministry of Environment suggests that the 1997 system over a ten year period might have had an isolated improvement effect of around 1% in terms of km/litre, and in her PhD dissertation Helle Ørsted Nielsen argues that such taxation systems have had little or no effect on new purchases in a Danish context (Berlingske Tidende, 2007; Ingeniøren, 2007). Considering the lack of impact that such a system has had so far, combined with a drop in

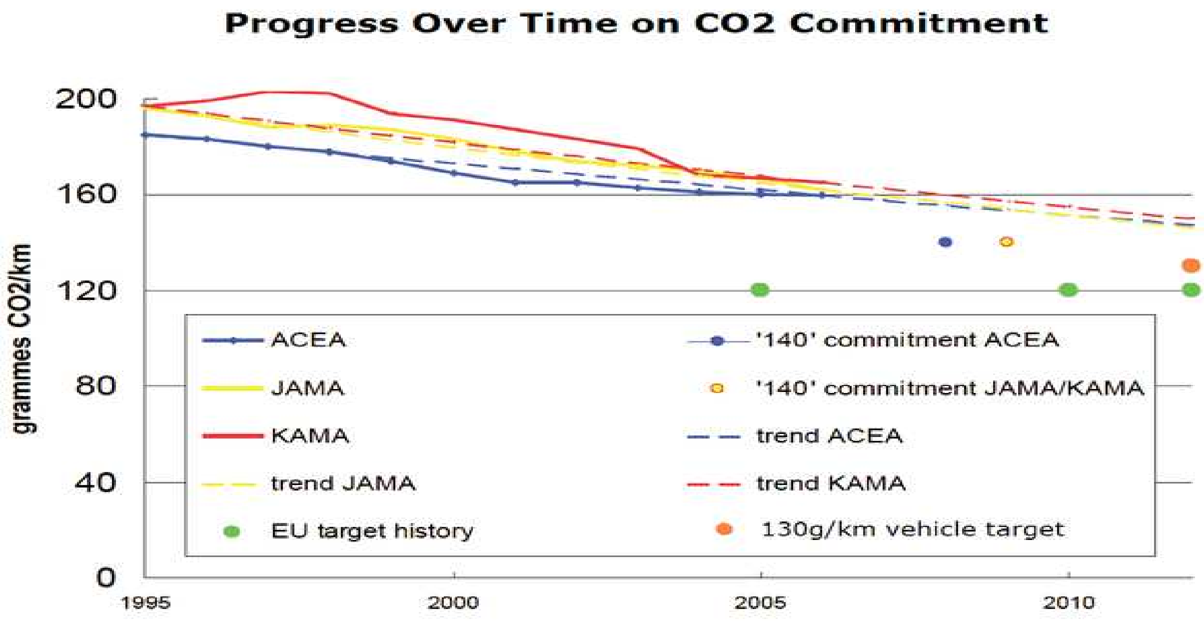

Figure 10: Average CO_2 emission standards for new cars produced by European (ACEA), Japanese (JAMA) and Korean (KAMA) car manufacturers that are sold in Europe (Green Car Congress, 2007).

prices for older models south of the border, it seems unlikely that the new system is going to offer any significant improvements to sustainability in transport sector. Even if we look outside Denmark there is not much salvation to find, as reduction goals have proved to be both hard to reach consensus on and even harder to live up to. Figure 10 shows the development in average new CO_2 emissions for new cars sold in Europe, and it is clear that the rate of reduction will have to happen at a much faster pace than currently if the EU goals are to be met, but already now the automobile industry is lobbying for higher emission standards with a system based on vehicle weight. Sunk costs and strong path dependencies[9] in the automobile industry make it hard to suddenly achieve a complete overhaul of the technology used to power vehicles, which serves as a barrier to reaching reduction goals as illustrated in figure 10.

[9] Sunk costs here refer to any investments that have already been made and would more or less be 'wasted' if new technology is not compatible with these products or services, such as R&D costs for improving small internal combustion engines (ICEs) if electric vehicles take over the private transport sector. Path dependencies describe a supply network, i.e. for ICEs there would be a large incentive for oil producers to promote more efficient ICEs instead of electric power systems. Similar interests are held by geologists locating oil or logistics companies organizing transport of it, and the complexity of these networks results in a large amount of stakeholders, who all have an economic interest in working against alternative solutions.

Despite environmental issues having been placed high on the political agenda for more than a decade, and many countries obligating themselves to meet international agreements on emission standards such as the Kyoto protocol, we are still not witnessing sufficient reductions. An optimistic perspective would then be to achieve these goals within a longer timeframe, but as consumption continues to grow the per unit emissions will need to be reduced even further, and the inability to meet the goals set out now thus constitutes a major obstacle for reaching sustainable development in the long run. As long as people are reluctant to actually buy energy efficient cars it does little good that technology exists to enable more sustainable transport, and even if they were forced to do so the results presented in figures 6, 7 and 8 indicate that energy efficiency by itself cannot be expected to make transport sustainable.

3.5 New frontiers

In addition to efficiency enhancing technologies having so far proved inadequate in reducing total consumption they have also largely been targeted at compact, small-scale surface vehicles; cars designed for use in urban areas. Little or no attention is given in politics or planning to aviation, even though it is a section of transport which is largely free of emission taxation, has been expanding rapidly since it was introduced for commercial use and looks to be one of the big barriers to sustainable transport in the future (Cohen, 2009). I shall try to avoid straying too far into the area of airborne transport here, but the trend of increased aviation is a good example of changing patterns of consumption for which engineers have yet to conjure up some magnificent technological device, that will suddenly remove environmental damage being caused by them. If vehicle efficiency at some point reaches a level that makes land based transport sustainable it is likely that we are then faced with the problem of making airborne transport sustainable as well. The point is that unless sustainability is somehow included in the initial phases of new technology, it is very difficult to change this rapidly at a later point due to sunk costs and path dependencies.

As of now the lack of CO_2 taxation on air and sea based transport does not imply much concern for sustainability in these areas, and while both of them are included when calculating GDP they are often conveniently excluded when calculating energy use, which lead to false argumentation of a possible decoupling actually taking place (Information, 2007b). This was also the case when former Danish Prime Minister Anders Fogh Rasmussen in his 2006 opening speech announced that Denmark had managed a 50% increase in economic activity over 25 years without increasing energy usage. By including energy consumption from air and sea based transport we see that the increase in energy use has actually been larger than that of GDP, and former consultant in Søfartsstyrelsen (the Maritime Department of the Danish Ministry of Finance) Ralph Sylverstersen claims that the lack of transparency in documented energy use for sea based transport makes it hard for outsiders to judge the impact on energy use from this sector (ibid.). However, leaving it out of official figures doesn't make the problem disappear, and postponing efforts by giving people a false sense of security only enlarges the required reduction in energy use for future generations.

Intelligent Transport Systems (ITS) is another example of a technological approach to sustainable mobility, which have received a lot of attention and positive comments lately in Denmark, particularly by the Danish Infrastructure Commission who holds great expectations to ITS solutions in relation to both congestion and emission problems (Infrastrukturkommissionen, 2008). ITS in the sense that it is used here basically refers to any kind of effort, where information and communications technology is applied to either infrastructure or vehicles, and the intention is usually to improve safety and comfort as well as reduce travel time and fuel consumption. A GPS or even a standard radio could be examples of ITS solutions that offer additional information about relevant conditions to the driver, which is then used to aid his decision making in regard to choice of route for example. Automatic speed pilots are another type of driver assisting technology and new products are continuously presented as the latest breakthrough in ITS. The aim here is to ease the task of driving by either providing the user with additional data to reach more optimal decision making or simply by a computer taking over the decision making.

The potential for such measures to improve both in efficiency and popularity certainly exists, and they have indeed managed to reduce certain adverse transport related effects such as congestion, fuel efficiency and hazardous speeding in some tests. However, they have also been observed to cause increased driver frustration and reduce driver awareness (Comte, 2007; Spyropoulou et al., 2007). Additional information systems divert driver attention away from the actual road environment, including simple tasks such as tuning to different radio stations (McKnight & McKnight, 1993). With the introduction of GPS, IMS and HUD[10] technologies there is now an increasing amount of information distractions available, which results in a higher amount of traffic accidents. Systems such as automatic speed control and ABS[11] have been observed to increase the drivers' feeling of safety, causing them to adapt riskier behaviour and employ higher speed, especially in risky conditions such as rain, snow or fog (Spyropoulou, 2007). Such solutions can also trigger certain behavioural changes under specific circumstances, particularly when drivers feel that they are giving up too much control to an automated system. Drivers exhibit a tendency to more aggressive behaviour, when driving assisting technology dictates their choice of route between destination A and B or adjusts vehicle speed to changing speed limits, and will sometimes override the system to make hazardous manoeuvres in order to make up for the time they feel they have lost from a seemingly ineffective system (Persson et al., 1993; Comte, 2007; Spyropoulou et al., 2007).

ITS solutions might solve some of our current problems, but they will also present new ones as well as enhance others if their implementation is not closely monitored. All in all there should be no doubt that ITS have a great potential for making transport more efficient and more fluent, but what I have tried to sketch out here is an understanding of the need to integrate them intelligently and be aware of their limitations, instead of blindly advocating ITS and other new technology as our saving grace, which I will argue has been the perspective held by the Danish Ministry of Transport and other government institutions (Infrastrukturkommissionen, 2008; Vestenbæk et al., 2008). Such views help blackbox[12] the sustainable mobility debate into a concern with how new technology can reduce environmental impacts of transport, but in reality there is a limited amount of reduction to be gained

[10] Global Positioning System, Instant Messaging Service and Heads-Up Display respectively.

[11] While ABS technically qualifies as an ITS solutions its intention have obviously not been to help reach sustainable mobility, and neither would I dismiss it as a hazardous technology that ought to be removed from cars. I am merely pointing to the fact that ITS solutions does not only influence driver behavior the way it was intended by design, but will usually be accompanied by a set of unexpected influences, which might affect sustainability, safety or something completely different.

[12] Blackboxing here refers to a process in which the focal points of a discourse have been reduced to a simple set of identifiable nodes, resulting in the exclusion of other perspectives (often antagonisms to the blackboxed perspective). In the case of technology blackboxing in the sustainable mobility discourse it can mean that individual responsibility for transport behaviour is disregarded as an instrument to achieve sustainability, since technology is dominating the agenda and people put their faith in technocratic fixes to solve the issue of transport's adverse environmental effects.

through such solutions, and as I shall argue in chapter 6 they can actually increase total energy consumption and emissions instead of reduce them.

4 Modal switch

The second of the three scenarios is focused towards the impact that a shift from private car use towards more public transport can be expected to have on the potential for decoupling economic growth and environmental impacts from transport. The scenario will aim at both the instruments of achieving a modal switch, the barriers against their implementation and the decoupling potential of the approach in general. The analysis builds on a simple forecasting of future traffic volume, of which private motorized transport is then spread onto public transport systems depending on the respective share of total volume in the current transport system. A discussion of the role of public transport in contemporary and future transport systems can also be found at the end of this chapter.

4.1 Public transport: the new paradigm?

The second scenario is based on an approach that focuses on switching our preferred mode of transport from cars to public transport, in an effort to lower the adverse environmental effects of transport. Provided that public transport has a sufficiently large user base it is less polluting per driven passenger kilometre than cars due to higher capacity in each vehicle. While technological improvements is still the dominating approach in politics the modal switch route has gotten increased attention lately, which in Denmark became evident with the transport investment plan announced in January 2009.

In the last months leading up to the final version of the plan there was increased public debate regarding the lack of public transport investments and efforts to reduce CO_2 emissions. Heavy critique came from a range of different actors, including transport researchers, politicians and trade organisations (Børsen, 2009; Ingeniøren, 2008a; Jyllandsposten, 2008). Immediately after the final plan was announced, ten traffic researchers from different Danish universities and organisations were interviewed regarding their expectations for the plan to achieve sustainability in the transport sector, and the answer was a clear no from nine of them. While the plan has been praised by the politicians in charge of it as "*a historically green plan*" (Ingeniøren, 2008b) there seems to be a clear consensus from the academic community that this is not the case, which a few citations from the above mentioned interviews clearly shows (Information, 2009):

> "*This traffic policy looks like the one we've had for many years [...] it is business as usual.*"
> Jens Rørbech (Danish Technical University)
>
> "*You can enjoy a few raisins on the cake; the rest is just served in a new way. [...] The government is using an old trick where they add up the money they have saved over the past years to make it sound tremendous [...] it is no increase [in terms of funding].*"
> Uffe Jacobsen (Transport Economic Association)

> *"A lot of the plan is about improving the existing public transport facilities with the one hand and then expanding the road network with the other [...] they forget that there are people in the other end who have to change their habits. It is not enough to improve worn tracks and traffic lights that should have been done 20 years ago."*
> Malene Freudendal-Pedersen (Roskilde University Center)

Looking at these quotes it doesn't seem like Denmark is heading towards any significant increase in public transport, so the aim of this scenario will be slightly different than the previous. Instead of analysing the expected performance after a given timeframe I will do an analysis of how the environmental impact from transport would look if a paradigm of car use was shifted towards a paradigm of public transport.

4.2 Cars dominating the landscape

In this section I will divide the modal switch scenario into three sub scenarios simply for the sake of illustration; scenario 20, scenario 40 and scenario 100. The numbers simply to the percentage of reduction in driven passenger and vehicle kilometres for cars and motorcycles, and at first they might seem drastically high. This is fully intended and meant as an investigation of the possible environmental gains that a successful modal switch could offer. Obviously a complete reduction (100%) is very unrealistic and should not be viewed as a goal but rather as an illustrative example of the maximum potential of this approach for the sake of comparison.

The data for both passenger and vehicle kilometres travelled is provided by Danmarks Statistik (Statistikbanken, 2008), and is split on cars, bicycles, mopeds, motorcycles, cars, taxis, vans, trucks, busses, metros, trains, ferries and planes. To give a reasonable overview for this report ferries and planes have been omitted from this analysis due to their low share of total transport, as well as the problems of modal switches between bus/train to ferry/plane. To further simplify the analysis a number of categories have been left out due to a minimal share of total transport (mopeds for example) or lack of relevance for passenger transport (vans and trucks), while others have been calculated separately but combined in the same category for presentation in the report (trains and metros for example). The data in use is presented in table 5 and represents the 2004 transport volume for passenger transport on the Danish infrastructure system.

Means of transport	PKT (mil. km)	PKT %	VKT (mil. km)	VKT %
Cycling	2230	3.2	2230	5.9
Private Car	51809	75.5	33618	89.9
Taxi	408	0.6	510	1.4
Motorcycle	799	1.2	644	1.7
Bus	7300	10.6	643	1.7
Train	6074	8.9	60	0.2
Total	68620	100	37705	100

Table 5: Passenger (PKT) and vehicle kilometres travelled (VKT) in Denmark 2004

Looking at table 5 it is clear that car use account for most of the Danish passenger transport with 75.5% of PKT, a number that is slightly below that of the EU15 average (Infrastrukturkommissionen, 2008). We also see that vehicle kilometres travelled are noticeably lower than passenger kilometres travelled for most motorized means of transport (excluding taxis as chauffeurs are not included), but for private cars the factor between PKT and VKT is only 1.5 versus 11 for busses or more than 100 for trains, meaning that cars only carry slightly more passengers than motorcycles (with a factor of 1.2) per vehicle. This factor has decreased over the last decade for cars, meaning that VKT has been increasing faster than PKT (Infrastrukturkommissionen, 2008). This indicates that the motivation behind a modal switch seems valid at least, as we drive longer and further in our cars each year without increasing the amount of actual passenger transport at the same rate. Surely this is not a sustainable development, so let us move on to what more public transport can offer.

4.3 Less cars and motorcycles, more trains and busses

For the three sub-scenarios (scenario 20, 40 and 100) I will be keeping the 2004 total PKT constant. Bicycles and taxis will keep their current share of total transport as these are expected to change drastically with a higher focus on public transport. People might be more encouraged to use their bike if increased public transport creates a safer and cleaner local environment, while better public transport facilities could also result in previous bicyclists shifting to the use of public transport. Taxis are usually not used for everyday commuting or shopping trips, and are unlikely to take over these tasks due to the large price gap between taxis and cars/public transport. Bicycles and taxis do however experience a small growth to indicate induced traffic from reduced car use, which happens at the cost of busses and trains. However, the transport demand resulting from the reduced PKT for motorcycles and cars will almost solely be handled by busses and trains, and while such a model is very simplistic it does serve our need for this analysis, which is to find an indicator of public transport's ability to achieve sustainable mobility. The resulting data for the three scenarios can be seen in table 6.

Vehicle	Base 2004	BAU	Scenario 20	Scenario 40	Scenario 100
Cycling	2230	2518	2644	2776	2915
Private Car	51809	58492	46794	35095	0
Taxi	408	461	484	508	533
Motorcycle	799	902	722	541	0
Bus	7300	8242	14644	21043	40405
Train	6074	6858	121785	17509	33619
Total	68620	77472	77472	77472	77472

Table 6: Resulting transport split in 2019 if busses and trains are to handle the majority of the transport demand arising from a reduction in car and motorcycle traffic (mil. km).

Due to the high share of passenger transport done by car we can see from table 6 that public transport is to handle almost double the amount of passengers if car use is to be cut by 20%. Further reduction of car use seems completely unrealistic with current public transport solutions, when looking at the number of passengers that public transport would have to service.

The numbers in table 6 are highly exaggerated when comparing with actually modal switch results in the past, where efforts to promote public transport have usually only resulted in a few percentages of people actually switching from car to public transport. Again, the message here is not to paint a

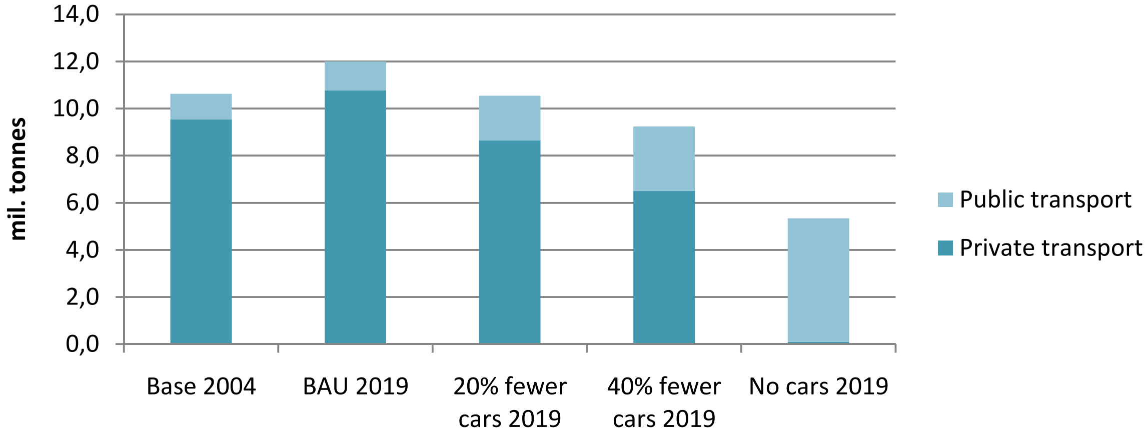

Figure 11: Total CO_2 Emissions In Transport Systems With Various Levels Of Car Dependency.

Scenario	Base	20% car reduction	40% car reduction	100% car reduction
Difference	+12.9%	-0.8%	-13.0%	-49.7%

Table 7: Difference in CO_2 emissions compared to base 2004 level.

realistic picture of the likely impact that current modal switch approaches would result in, but rather to question the rationale behind these approaches. To offer any noticeable environmental improvements a modal switch needs to switch a significant amount of people moving away from using the car as their main mean of transport, but due to the high share of car users in the transport system, this means that public transport is going to need a lot more capacity and accessibility that it currently has, if it is to service the former car users. It would likely require both regulations to discourage people from using their car as well as improving the service level of public transport, and even then the numbers of table 6 seem out of reach. However, if we assume that we could actually cover a 20%, 40% or 100% reduction in car use by public transport systems and also make people use such systems, then what would the actual environmental gain be? Based on emission data from Delft (Essen et al., 2003) I have calculated the total amount of CO_2 emission from passenger transport in each of the scenarios from table 6, and the results are shown in figure 11. For the three last scenarios the expected efficiency of public transport has been increased, as a massive increase in users must be expected to result in fewer busses and trains driving around empty, which have long been a major source of inefficiency in public transport.

As seen in figure 11 there are indeed a benefit of reduced CO_2 emissions from a modal switch, but the gains are not overwhelming. In the BAU scenario emissions are expected to increase by 12.9% over 15 years. Reducing the use of cars for passenger transport by 20% would thus only bring the emissions close to the 2004 level, while requiring significant changes to the public transport system and regulation on car usage. The government's goal for CO_2 emissions is a reduction of 25% in 2030 compared to 1988 (Regeringen, 2002) which equals close to 50% reduction compared to 2004 levels. Table 7 shows the changes in CO_2 emissions for each scenario.

As seen in table 7 it would be necessary with almost a complete reduction of car use to reach the government CO_2 goals for transport with expected 2019 traffic levels. Reduction by modal switch has then used most of its maximum potential as we have moved almost all car based passenger transport to public transport. However, growth in transport volume would still be expected to continue towards 2030, meaning that modal switch cannot cover the increased emissions that must be expected in this period. This brings food for thought to a discourse in which public transport is seen as a saint and the private car as the great sinner. While public transport is indeed more energy efficient than the private car, we still won't reach a 25% CO_2 reduction compared to 1998 even if all cars were to be removed by 2030, and all in all it seems highly unlikely that a modal switch is going to solve the CO_2 problem alone. This was never the intention of the approach of course, but table 7 and figure 11 display obvious limitations in blindly advocating modal switch as a solution to the environmental problems caused by transport.

Apart from not living up to the reduction goals it is of course also very unrealistic that we will have a public transport system to cover all passenger transport in a little more than 20 years from now. Unless price, travelling speed and frequency of public transport is severely improved it does not seem likely that people are willing to engage in such a modal switch in the first place anyway. Such performance improvements are likely to be associated with a reduction in energy efficiency, and unless this energy can be provided from CO_2 neutral sources this would reduce the gains from switching to public transport even further. This does however not mean that public transport should be abandoned as it offers other benefits than merely reduced CO_2 emissions, and can receive the same efficiency upgrades from technology that can be implemented in cars. Public transport will always be important for groups of society who lack mobility alternatives, and with increasing transport demand we will also witness increasing congestion problems, which will increase demand for transport systems which require less physical infrastructure to operate efficiently.

4.4 Mass transport for the masses

Reducing costs or travel time for public transport services are some of the common ways of attracting motorists. However, reduced travel time and pricing of public transport might make them more appealing not only compared to that of a car, but to various means of transport in general. This could mean that pedestrians and bicyclists, who previously did not engage in motorised transport, now also take part in this type of travel, which could lead to an increase in the total motorized transport volume, and thus outweigh the benefits gained from moving people out of cars and over to public transport (Hillman, 2004). Reduced travel time has also traditionally been connected with greater engine capacity, which in turn reduces fuel efficiency and thus further reduces the benefit of emission per PKT, that is gained from moving users from cars to public transport. However, reductions in travel time are also possible by favouring public transport over private i.e. through separate bus lanes or bus priority at junctions, which increases the attractiveness of public transport both absolutely and relatively in relation to private transport as such solutions would not involve any improvements to travel times by car.

An important aspect of a modal switch, that is often forgotten or overlooked in both academia and politics, is non-motorised transport like pedestrians or bicyclists. While these forms of transportation have obvious limitations due to the slow speed at which they take place, and thus the range in which they can effectively operate, they offer equally obvious benefits for common problems in the transport sector such as congestion, pollution, public health and transport flexibility. Denmark has traditionally been known as a country where bicycling covers a relatively high amount of transport demand compared to other countries, although the share has declined somewhat over the recent years. It is however mainly in the capital area that this becomes evident, with citizens in Frederiksberg biking more than 3 km/day (12% of total PKT) on average compared to only 1.2 km/day (3.2% of total PKT) in Aalborg, the 4th largest city in Denmark (GØ, 2008[13]). Aalborg has the

[13] There might be systematic underrepresentation of biking in this data, but it still indicates the differences between the largest Danish cities. I will briefly return to this problem in section 5.3.

somewhat unambitious goal of a 10% increase in bicycling towards 2020, which would need to be increased by a factor of six just to reach the current level of Odense, the 3rd largest city in Denmark. In the report from the Danish Infrastructure Commission of January 2008 there is no recommendations regarding improvements for non-motorised modes of transport at all, and in general investments and efforts towards modal switch seems to be minuscule or nonexistent in the case of bicyclists or pedestrians.

From a sustainability perspective the lack of attention towards non-motorised transport modes seems counterintuitive to the government goals of massive CO_2 reductions in the transport sector, and a recent study from Oslo recommends at least a 6% bicycle share of total PKT in order to reach sustainable mobility (Holden, 2007), which only the capital area of Denmark can currently live up to. Pedestrians and bicyclists need incentives and encouragement just like any other type of transport to choose these modes of transport, which include efforts to improve safety and comfort along sidewalks and bicycle paths. Constructing separate biking lanes and closing streets off for motorised vehicle transport can encourage more people to shift to using their feet or bike, while close proximity to high speed motorised traffic and high degrees of air pollution can discourage them.

Attitude as a precondition for behaviour has been a central topic of research in both social psychology and consumption theories since early in the last century (McGuire, 1986). In social psychology attitudes are thought to help organize and structure the chaotic nature of the world by serving certain psychological functions for the holder of them, and thereby directing behaviour. A central aspect of attitude research is then obviously focused on how behavioural change can be achieved through attitudinal change, as well as if any causal relationship actually exists. In relation to the discussion of sustainable mobility the concept of green attitudes suggest that more environmentally responsible users will try to reduce energy consumption for passenger transport or choose less polluting modes of transport and that environmentally responsible mobility behaviour should thus be reinforced. Enforcing such attitudes could thus compliment a modal switch approach.

Private motor vehicle transport has been claimed to constitute a number of psychosocial benefits over other means of transport, including prestige, autonomy and protection which are not usually taken into account when forming transport policy (Ellaway et al., 2003). There seems to be no dominating consensus on the causality between socio-demographic and psychosocial factors in regards to transport behaviour (Anable, 2005; Hunecke et al., 2007), but part of this could be due to the general lack of attention given to these topics in orthodox economic studies (Black et al., 2001). In a study from 1999 sociologist Mette Jensen finds that both users of private car as well as public transport view the car as a sanctuary that signals status and independence, indicating that people without access to car aren't necessarily voluntarily in that position. Apart from providing alternative transport modes to that of private car use, one of public transport's primary roles is then also to provide mobility to people who cannot afford a car (Jensen, 1999). However, results from Copenhagen by Næss & Jensen (2005) indicate that the difference in use of public transport between low and middle income groups is rather small, even if a trend can still be spotted. The results instead show that the chosen public transport modes differ with different levels of income, with lower income groups primarily using busses and middle to high income groups primarily using trains. Neglecting buses can thus still cause mobility inequity and social exclusion, and as rail based transport is not a viable option outside Copenhagen (in Denmark that is) I still see some merit in Mette Jensen's argumentation in a Danish context. Furthermore, as lower income groups also have a larger share of bike usage, this means that while public transport share might not differ much then car share will still be correlated with income. Another cause of inequity stems from the suggested psychosocial benefits only applying to the actual users of the cars, while the increasing number of cars in the landscape has negative consequences for the psychosocial well-being of the general population, particularly in congested urban areas (Steensberg, 1999). Car users show a high degree of knowledge and concern for the environmental impact of their chosen means of transport (Jensen, 1999), but as car use and adverse environmental effects of transport keep rising it seems that the psychosocial benefits of car driving outweigh the general concern for the environment.

These psychosocial benefits could be related to the changing ways in which we engage in social interaction. Sociologist John Urry advocates a change from the basic object of sociology as 'society' to 'mobilities' instead. Society has long been a central focal point in the sociological discourse in the definition that encompasses meanings such as nation state, citizenship, and national community (Oldrup, 2005). The processes enforcing this change means that the traditional notion of society is no longer capable of handling the complex consequences of diverse mobilities due to the intersecting nature of contemporary sensuous relations, networks, societal borders, regions and flows (Urry, 2000). The sociological framing presented by Urry could offer part of the explanation as to why values such as mobility, freedom and independence are so manifest within contemporary society:

"the self-expanding character of the car system [...] produced and necessitated individualized mobility based upon instantaneous time, spatial fragmentation and coerced flexibility" (Urry, 2008: 272). The values described in this citation could in my opinion just as easily represent other contemporary social systems than that of the car, such as those of entertainment or information. These systems also exhibit increasing degrees of requests for instant access, fragmented space and flexible compatibility, and as such can be regarded as representative for (mainly western industrialised) societies as a whole, rather than just transport and mobility. These values call for individual transport solutions as public transport systems are simply too restrictive; waiting for a bus is not instantaneous mobility, fragmentation only goes as far as public transport services are available and flexibility is inherently limited in a system that is compelled to organize transport through systematic routine.

The car as a system is thus much better suited to meet the mobility demands of the modern society than public transport is, which is perhaps not surprising as the car has been an active instrument in shaping this society. These mobility demands have resulted in what Urry claims to be the death of public transport as we know it. He claims that the model of "*publicly owned, managed and timetabled buses, trains, coaches and ships [...] has been irreversibly lost*" (Urry, 2008: 272). This rather gloomy conclusion for public transport solutions does however not necessarily have to be true, at least not for all aspects of mobility, which is also evident from the success of public transport systems around the world (Vienna being a good example). Commuting and work related transport in general are rarely spontaneous activities and can often be planned around a public transport timetable, or at least more easily so than leisure time travel for instance. This is of course assuming that an effective public transport system is in place. Urry's position does however raise questions regarding the role of public transport systems in current and future societies, especially since they seem to be conflicting with a set of core values in contemporary western societies. Can a modal switch take place through sheer encouragement if it conflicts with fundamental human values in our society? Is it possible to change these values and the perception of society? If so, how do we do it, and is it compatible with an economic growth agenda?

5 Demand management

The last of the three scenarios is focused towards the impact that a volume reduction of transport activities can be expected to have on the potential for decoupling economic growth and environmental impacts from transport. A multitude of instruments can be used for this purpose, but for this study I have chosen two of the most commonly suggested in academia and politics; land use and fiscal regulation. As was the case in the first scenario they do not share equal representation within the analysis, as the primary focus will be on land use strategies. However, due to the attention that fiscal instruments such as road pricing have gained over the last couple of years from policy makers it seems relevant to include it as an instrument as well. A brief discussion on the impact of information and communications technology can also be found at the end of this chapter.

5.1 Less transport, fewer problems

The third scenario is based on reducing the actual amount of transportation and thus a somewhat different approach to sustainability than the two first scenarios, which focused on lowering the environmental impact per unit of transport. Scenarios one and two both allow for the same transport demand to be met in new ways (technological advance and modal switch respectively), but a volume reduction implies that transport demand has to be lowered and that we would need to adjust to a society in which we are probably going to be less free than previously in terms of mobility... or does it? Research on the connection between land use planning and transport demand suggests that this demand can be lowered by changing the physical structure of urban form. This means that planners can avoid infringing on citizens' personal freedom in regard to transport choice, but still reduce the total amount of transport through proper design of the urban structure in terms of location. In this chapter I will attempt to outline the potential environmental benefits from adhering to such an approach, as well as problematic issues related to it.

Studies on the connection between urban structure and transport demand has not reached consensus on the degree of impact that physical urban form influences on transport demand, but the general view presented here is that there is widespread support for a strong correlation between population density of residential areas, their distance to a city centre or sub-centre and the amount of transport that is undertaken by people living in these areas (Hartoft-Nielsen, 2001; Holden, 2005; Mogridge, 1985; Næss & Jensen, 2005). By creating proximity between urban activities planners can encourage a reduction of transport demand simply by reducing the distance required to complete many routine activities. In many European cities there has been a tradition of locating core service functions, businesses, stores, public agencies and workplaces in central areas of the city. Similarly, the main node of the public transport system is also usually found in the city centre, just as the bulk of the housing stock is often located in close proximity to it. Residents living here thus have the opportunity to carry out a large number of activities within a small geographical area compared to residents in more peripheral areas. Inner city living is therefore promoting the use of non-motorized means of transport such as biking or walking for errands within this area (Næss & Jensen, 2004). In the rest of this chapter I will present data from various studies on the relationship between urban structure and transport demand based on the theoretical perspective that has briefly been outlined here. Credit for this data and much of the interpretation of it goes to the original authors, but I shall use it as a basis for exploring the potential of reducing the adverse environmental effects of transport through land use planning.

5.2 The case of Oslo

Holden (2007) describes the Norwegian SusHomes project carried out in Oslo, where surveys of energy consumption were conducted in eight residential areas with different levels of population density and housing types, as well as located at varying distances from the city centre, local sub-centres and public transport. The areas thus represent different types of land use characteristics which allows for a comparison of the influence of such characteristics on energy consumption for various activities (including transport). The energy consumption for everyday travel and leisure travel by car can be seen in figure 12. The energy consumption for housing and long-distance leisure-time travel by plane has not been included here, as the focus of this report is on reduction of transport volume through design of the physical urban structure. Although some researchers, including Holden (2007), support theories that also link leisure-time travel by plane to urban structure as compensation for lack of access to gardens and other green areas, I have not explored these theories in any detail, and at least not in a sufficient degree for inclusion in this report.

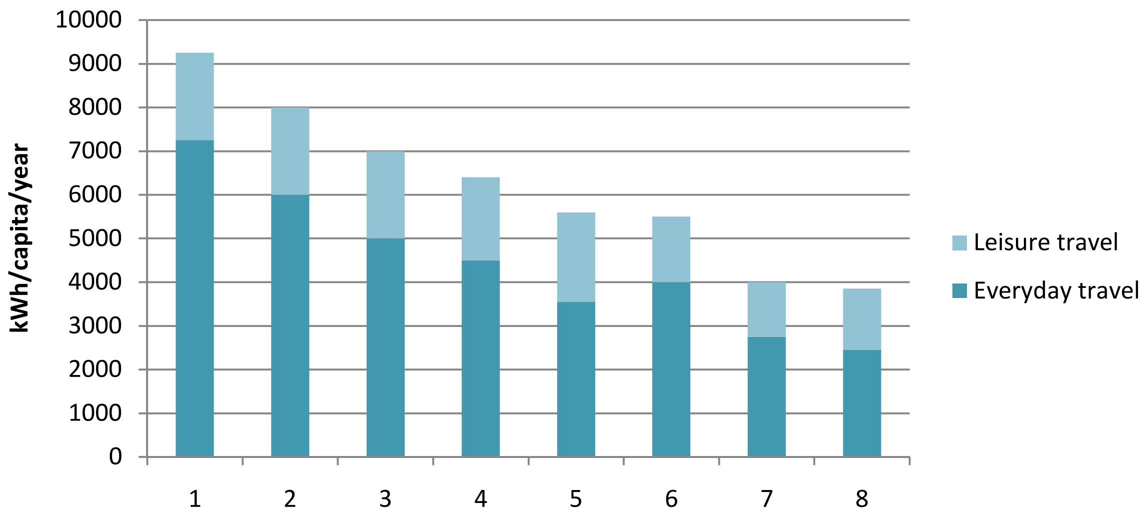

Figure 12: Energy consumption for the eight residential areas in the SusHolmes project. Based on Holden (2007).

As is evident from figure 12 there is a noticeable difference in the energy consumption for transport between the different areas included in the SusHolmes project. Areas 1 and 2 are characterised by low relative housing density and long distances to the Oslo city centre as well as tram or subway stations. Area 1 is also the only of the eight areas that is located far from any local sub-centres in Oslo. If we move along the horizontal axis of figure 12 a trend of increasing housing density can be observed as well as closer proximity to the Oslo city centre, local sub-centres and public transport nodes. The dominant housing types also move from single family or row housing in the areas with the highest energy consumption toward multifamily housing in the areas with the lowest energy consumption. A multivariate regression analysis identifies distances to the Oslo city centre and local sub-centres to be the most influential land use characteristics on energy consumption for transport. These results are supported by other studies (Næss et al., 1995; Næss, 1996; Næss, 2006b) which also finds distance to have a stronger influence on energy use than socio economic variables such as income level, age or car ownership. Næss et al. (1995) found that when looking at individual households the distance from residence to city centre was the most influential of the five variables fulfilling a 0.10 level of significance (table 8).

Variable	Beta	Level of significance
Distance to city centre	0.472	0.0000
Cars per adult household member	0.318	0.0000
Children per household	- 0.262	0.0000
Access to nearby service facilities	- 0.158	0.0012
Access to nearby public transport	0.096	0.0920

Table 8: Standardized regression coefficients for independent variables influencing travel distance among respondents living in thirty selected residential areas in Greater Oslo (Næss et al., 1995). Data from individual households (N=321).

An analysis was also carried out using the residential areas as units of analysis which only enforces the relationship between location and transport demand (table 9). As the individual households must be assumed to represent a variety of individual values this may in fact also be a more relevant study from a planning and policy perspective, as it could prove a lot more difficult to influence the personal preferences of individual households rather than the physical frames of a residential area.

Variable	Beta	Level of significance
Distance to city centre	0.755	0.0000
Income level	0.205	0.0665
Area per capita (local)	0.204	0.1019

Table 9: Standardized regression coefficients for independent variables influencing average travel distances (Næss et al., 1995). Data from residential areas (N=30, average values among respondents from each area).

5.3 Reducing transport demand

As Norway and Denmark are very similar I have based my estimates of transport reduction on results from Oslo and Copenhagen. I have made a crude estimate of the possible effect on passenger transport from land use strategies that are in line with the compact city principles. With data from Statistikbanken (2008) I have calculated an expected share of new construction compared with the total building stock towards 2019 and 2050 in Denmark, which have then been combined with a potential 20% reduction in transport if this new construction is planned with distance between city centres and workplace/residential locations, housing types and population density in mind (based on Næss et al., 1995; Næss, 1996; Næss & Jensen, 2005; Holden, 2007; Litman, 2008[14]). The land use effects have been combined with results from Eliasson et al. (2009) on the effects of road pricing in Stockholm as well as results from Proost & Dender (2008) on modelled reduction gains from transport pricing, and the combined estimate can be found in figure 13. In these estimates the modal switch effects of neither land use strategies nor pricing have been included, and they are limited to the transport reducing effects of location and pricing alone. For a more detailed estimate such effects should surely be considered, but I feel that a simple model serves to illustrate the tendency that can be expected from demand reduction. Some of these effects are not mutually exclusive

[14] The potential is based on average reductions attributed to land use factors in these sources, and rounded off to 20% for sake of simplicity. The required accuracy for this estimate to give an indication of the reduction potential of a demand management approach seem to be sufficiently met by this, as outlined in section 1.5.

either as both changes in land use or pricing levels are expected to influence the same factors (for example the modal split as just discussed). However, I would expect diminishing returns from a combined effect of these two approaches since studies in transport behaviour have displayed the reluctance of car users to engage in actual modal switch, which implies that there is a floating limit of how many people can actually be moved from cars to public transport for example. I would also prefer keeping the three scenarios separate and such considerations will thus be discussed in a later chapter. For now it seems sufficient to note that a modal split from compact city strategies and increased transport pricing would surely not result in a diminished reduction effect but rather the opposite.

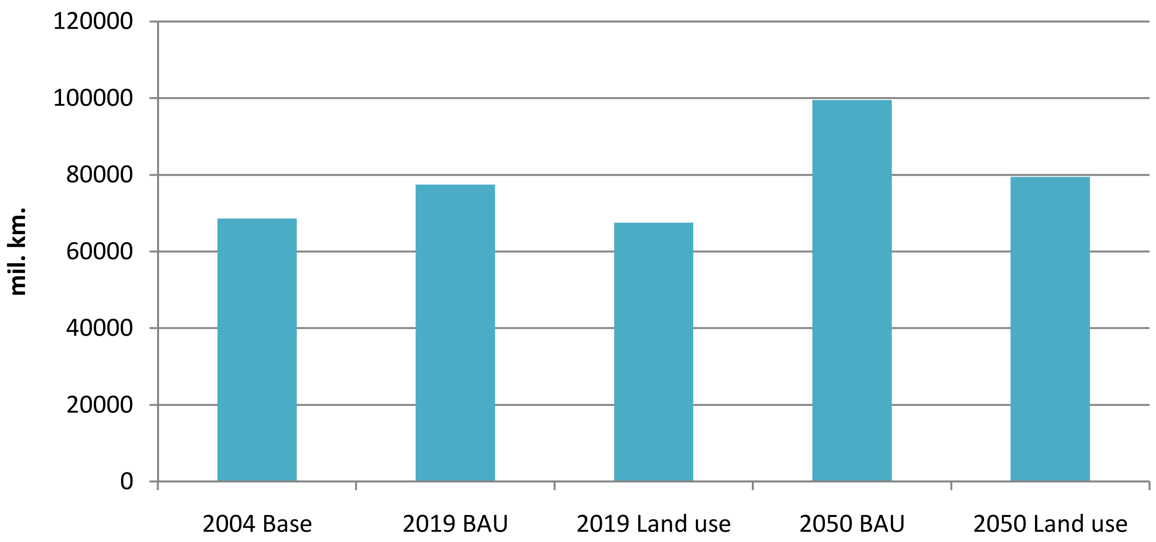

Figure 13: Estimated transport demand based on the implementation of compact city strategies and road pricing.

From figure 13 we see that a compact city approach with restrictions on car use does indeed offer noticeable reductions in total transport volume. Estimates were made for development towards both 2019 and 2050, with the former being a reference year for the modal switch analysis in chapter 4 and the latter being a more suitable timeframe for land use changes to have a noticeable impact. A reduction approach leads to around 15% less transport by 2019 and 25% less transport by 2050 compared to BAU scenarios, and these figures should be expected to increase if the resulting effects of a modal switch are included in the estimates. It does thus seem relevant to focus attention towards land use strategies and fiscal regulatory instruments in any approach towards sustainable mobility. Assuming that the modal split is identical to the current situation this would mean similar reductions in terms of CO_2 emissions. This means that a volume reduction approach to transport could achieve similar environmental benefits by 2019 as the 20% modal switch scenario in terms of CO_2 emissions (see figure 11 in chapter 4), and this is before including any effects that the resulting modal split of compact city planning would likely also bring about.

Information and communications technology (ICT) can be considered a technocratic solution along with intelligent transport systems (ITS) described in chapter 4. I have however chosen to include it here as it is primarily considered an instrument for demand management in regards to transport and mobility. With the introduction of home computers, laptops, wireless networks, cell phones and the internet information and communication has become practically instantaneous, and in theory have allowed for many tasks to be handled with a few button clicks. Booking a hotel for your holiday in Italy, managing your bank account and ordering groceries can all be done while sitting comfortably in your living room. Technology thus allows for much physical transport to be replaced by virtual traffic instead, which offers another potential source of volume reduction for transport. Especially the option for employees to work from home rather than in an office could potentially reduce a great deal of commuting. However, so far there has been observed a marginal impact from ICT on actual transport volume, and some even claim that it can be a source of transport generation rather than substitution (Denstadli, 2004; Hjorthol, 2002; Saffo, 1993). The arguments for this generator effect among others are that ICT enhances productivity and thus frees up more time for business travels, just as it enables relationships to be established with a wide range of actors you would not normally have access to, but whom you would likely end up needing to meet in person at some point (Saffo, 1993). ICT can instead be used to reduce peak hour congestion as people gain a more flexible work schedule, which indirectly reduces emissions but not transport volume as such. A possible side effect of this is fewer passengers for public transport as service will drop to a more dispersed and non systematic demand for transport during the day (Hjorthol, 2004). ICT does not only allow people to replace work at the office with work at home as wireless networks, laptops and netbooks are increasing in popularity and usage, but might as well take place at other locations, which would also involve physical transport to reach (e.g. a summer cabin)

The lack of impact from ITC on transport demand management only makes land use planning that much more relevant, as it goes to show how proximity has not lost its importance in relation to transport volume. Densifications of urban regions seem to go well in hand with traditional economic theories, of which one of the more important overlaps is probably agglomeration effects (Anes et al., 1997). Increased density and clustering offers increased physical accessibility, resulting in more efficient trade and interaction between businesses located within the cluster. Specialized workers, which make up an increasing share of the workforce in western societies, will also have more job opportunities to choose from, just as customers will benefit from increased competition on goods and services (VTPI, 2009). Haughwout (2000) finds that densification increases economic productivity, suggesting that physical infrastructure, parking facilities and urban sprawl development in turn reduces productivity. Supporting a reduction in transport volume does thus not necessarily have to be connected with an economic loss, which is the traditional position held by the Danish Ministry of Traffic (Trafikministeriet, 2004).

6 Discussion

"Our purpose is to consider what form of political community is best of all for those who are most able to realize their ideal of life. We must therefore examine not only this but other constitutions, both such as actually exist in well-governed states, and any theoretical forms which are held in esteem; that what is good and useful may be brought to light. And let no one suppose that in seeking for something beyond them we are anxious to make a sophistical display at any cost; we only undertake this inquiry because all the constitutions with which we are acquainted are faulty."

Aristotle, 'The Politics' (350 B.C.E.)

6.1 Societal consequences

In this section I aim to discuss the three approaches in the different scenarios in a wider context than just sustainability and economy. While a decoupling of these two factors was indeed the motivation behind this project, there are many other concerns that need to be considered in regard to their impact on society. It should be noted that these approaches are of course not mutually exclusive, i.e. land use planning and more efficient vehicle technology can surely both be implemented at the same time. However, there might be some societal consequences of one approach that makes it less desirable than others when looking beyond concerns for sustainability.

Barrier effects[15] could be one such consequence, particularly in relation to roads and vehicle traffic, which create a barrier for non-motorized traffic. Any motorized transport system limits the freedom of movement for pedestrians and cyclists, as they are restricted to move and confined in certain spaces if they wish to stay out of harm's way. This increases travel time as pedestrians need to reach designated junctions before crossing a road for example, it reduces general comfort and health due to pollution (both particles and noise) and it is associated with greater risk due to users of non-motorized transport being less protected than those of motorized transport, as well as the latter causing more harm on impact due to increased weight and speed. In general motorized transport can and should be considered a degradation of the non-motorized transport environment, and while the argument could be reversed to conclude similar restrictions for motorized transport caused by non-motorized transport, it should be obvious that impacts are not symmetrical, i.e. the increased risk in such a joint environment would surely be more hazardous to users of non-motorized than those of motorized transport.

The barrier effect thus reduces the attractiveness of non-motorized transport, leading to an increase in motorized transport which augments the reduction effect even further. People who express a desire to bike or walk feel forced to choose motorized transport due to heavy motorized transport activity (Davis, 1993). As a consequence mobility for the remaining users of non-motorized transport (of which some have no other option) is ultimately reduced. Some of these people are usually disadvantaged financially, and as such are more or less dependent on this type of transport (VTPI,

[15] Barrier effects here refer to limitations that one type of transport imposes on others.

2009), although in a Danish context biking is probably more common among higher income groups than in other countries. However, while the correlation of income and car usage might be less pronounced in Denmark it still exists, and increased levels of motorized transport is thus associated with an uneven distribution of benefits which favours the highest income groups.

Barrier effects are often excluded from transport modelling, or at least poorly accounted, for simply because much non-motorized transport is often associated with some complications when trying to include it in the mathematical logic of transport models. Moving around the city on feet or bike can often involve lots of small and sudden movements between destinations in close proximity, whereas motorized transport is usually more of an A to B type of transport. Many trips might also just include motorized transport for part of a the trip, and even if a bus ride takes up very little of the total transport time, the trip is usually labelled as a bus trip from A to B, just as walking to and from parking spaces is often ignored. VTPI (2009) argues that far more non-motorized transport takes place than what is indicated in conventional surveys and models, which means that demand is higher than what is currently expected[16]. Infrastructure investments to expand the road network suppress this demand and cause further congestion and degradation of the local environment due to noise and particle emissions.

How does the technology scenario fit into this discussion? If we return to figure 6 we might recall that many of the alternative fuels offered only small gains compared to existing technology. Biomass and electricity fuelled vehicles where the only alternatives standing out from the crowd, with electricity looking like the best choice by far due to the production problems associated with sufficient amounts of biomass (as discussed in section 3.3). Electric vehicles are less noisy than their ICE counterparts and have much smaller local emission problems, which could reduce some of the previously discussed barrier effects. Due to their reduced performance they could possibly also offer a reduction in traffic related accidents. However, for these benefits to apply we would need to assume that demand for such vehicles increase, and currently the price and performance are

[16] Næss & Jensen (2005) reports higher shares of biking for Frederiksberg than GØ (2008), which could be due to differences in which data was collected.

certainly a restraining issue for their widespread popularity[17]. New electric vehicles continue to increase in performance and drop in price, which will make them more attractive to consumers but at the same time with reductions to follow for energy efficiency and traffic safety. They aren't addressing the growing car dependency in western societies and will continue to incur congestion and demand for parking space. In relation to other technology related societal consequences I have briefly touched upon some of the problems associated with ITS solutions in section 3.5, and in general I would argue that a technocratic solution approach to sustainable mobility does little to enhance mobility for disadvantaged people (perhaps rather the opposite) and will likely enhance barrier effects due to increased car dependence. A modal switch approach would also be associated with barrier effects, but due to the lower speed, reduced frequency and possibility of placing infrastructure away from pedestrian and cyclist areas (i.e. metros) compared to a car based system, the effect here has a much smaller impact on the attractiveness of non-motorized transport. A volume reduction through denser land use planning would also encourage more non-motorized transport due to the reduced capacity of road infrastructure that such a development would result in.

Congestion arising from further car dependency also results in increased risk of traffic related accidents, although they tend to be less severe due to congestion's impact on average travelling speed (Janke, 1991), and reversely speed increases obtained from reducing congestion can thus result in higher per capita fatality rates from traffic accidents (Noland, 2001). On top of an increased risk of traffic accidents congestion causes delays, driver stress and pollution due to the gridlock situations that arise when traffic on a road network nears the capacity limit. A technocratic solution approach to sustainability does not solve the problem of road congestion, which in itself causes increased environmental impact due to reduced fuel efficiency from waiting in queues. The traditional solution in many countries (including Denmark) has been (and still is) to increase the capacity on the transport infrastructure network, which only leads to more severe problems of congestion at a later point (Vestenbæk et al., 2008). Congestion is seen as a limitation of the economic growth potential and as such should be reduced (Infrastrukturkommissionen, 2008), but following a predict-and-provide approach with road capacity expansions is not a very sustainable

[17] Some of the psychosocial benefits from car driving described in section 4.4 could possibly also be related to performance issues, meaning that the shift from ICE to electric vehicles could be associated with similar barriers as the modal switch from private to public transport.

solution to this problem, as it often leads to generation of more traffic that will end up congesting the new capacity. Apart from the emission problems that this increase in traffic volume will cause, there are also some obvious spatial constraints that limits the viability of capacity increases in the long run. The problem of congestion also tends to increase in size with wealth:

> *"Traffic congestion problems tend to increase with wealth because consumers purchase more vehicles, which greatly increases the amount of space needed for travel (a car trip typically requires an order of magnitude more space than the same trip made by walking, cycling or transit). Although increased wealth allows greater facility construction expenditures, the supply of land does not increase. Road and parking facilities must compete for land that is increasingly expensive due to competition for other uses, so land costs become an increasing portion of project costs and a limiting factor in roadway and parking capacity expansion. Although sprawl may seem to overcome this problem by shifting travel to the urban fringe where land costs are lower, dispersed development increases per-capita vehicle mileage, requiring more lane-miles and parking spaces per capita, so land costs continue to be a major constraint. As a result, congestion costs tend to increase and alternative modes and demand management tend to become more important with increased wealth".*
> (VTPI, 2009: 5.5-7)

It is clear from the above citation that a decoupling of economic growth and adverse environmental effects through mere efficiency gains does little to combat congestion, since economic growth in itself generates further congestion problems through an increase in traffic volume. ITS is associated with similar problems as it might reduce inefficient transport patterns, but in turn will free up capacity which overall results in a volume increase. Reducing traffic volumes through land use planning or transport pricing are not associated with such volume enhancing effects (obviously), and could in fact contribute to a congestion reduction if the physical frames were also to support other alternative modes of transport to that of the car, i.e. by combining it with a modal switch for better public transport options, improved biking conditions, reduced parking facilities for cars and road pricing programs. Apart from mass transit solutions being less energy consuming per passenger than cars, they also take up much less space, and a reduction of transport demand will in itself reduce congestion due to a reduction of capacity usage on the transport infrastructure networks. At the same time the reduced transport volume might encourage an increase in non-motorized forms of transport. Just as was the case with barrier effects then societal costs are also unevenly distributed among different income groups. When congestion occurs, users of public and private transport are similarly affected by delays, but it is the users of private transport that are the primary cause of congestion. As public transport users are generally from lower income groups than car users there is an uneven relationship between the people causing and carrying the burden of congestion.

Public health degradation due to increased levels of inactivity from use of motorized transport causes problems both for the people affected directly (reduced physical condition, more prone to disease) and society at large (reduced productivity, increased demand for health care services). Cerebrovascular diseases and ischaemic heart diseases are way above traffic accidents in leading causes of death in both developed and developing countries (Murray & Lopez, 1996), and while all disease cases obviously aren't directly linked to inactivity from motorized transport then it is believed by many experts that "*active transportation (walking, cycling and their variations) is the most practical and effective way for most people to maintain a healthy level of physical activity*" (VTPI, 2009: 5.3-3). Average trip lengths by feet and bike equal that of around 15 minutes of physical exercise, which is enough to improve the health condition for most people across demographic boundaries such as age and gender (Murphy & Hardman, 1998; Hýden, 1998). There are of course other ways to stay fit than through choice of transport, but due to the time and effort required to use a gym or be actively involved in sports, most people are unable to regularly make use of such alternatives, and active transport is thus often advocated as the most efficient and practical way of promoting public health through physical exercise (Cavill, 2001; Litman, 2006; VTPI, 2009). However, not only walking and cycling have been documented to have a beneficial effect on physical activity public health. Using public transport means an average of five to ten times longer walking distances involved than for trips made by car, and results in an increased chance of reaching 10,000 steps per day (recommended physical activity level) by a factor of four (Wener & Evans, 2007). Limiting the amount of transport needed (especially longer trips) through land use planning and fiscal regulation could thus benefits for public health compared to simply making vehicles more energy efficient, just as a modal switch from private to public transport could reap similar benefits (albeit with less impact than a modal switch towards more non-motorized transport forms).

So far I have largely dealt with negative impacts of transport in this chapter, of which private car use generate the most of. Critics might argue that car use also has a number of associated benefits, such as increased mobility and accessibility coming from driving a flexible, long range vehicle like the car. I would therefore like to point out that transport activity is indeed a necessary and important part of any society, but the cost of it is equally important. For example, not all travel can be seen as a benefit to society the way it is usually presented in cost-benefit analyses of new road construction. Here time savings usually carry the greatest weight on the benefit side, but while reducing total travel costs might increase productivity, it might also lead to more leisure travel, as the benefit of time savings is basically a reduction of costs that makes such travel more affordable. Furthermore, it is primarily reductions of industrial transport costs that increases productivity, where reductions of consumer transport often merely transfers economic activity from one location to another (VTPI, 2009). Low travel costs for consumers thus mainly result in people having an option of living further from their work or regularly buying groceries from shops other than the local ones, and neither of these choices produce much economic activity. Travel demand will continue to rise as costs are reduced even after basic mobility needs are met, which leads to 'excess' travel that might be perceived as positive from an individual perspective, but where costs are directed at society at large (accidents, pollution, etc.). Expanding the capacity of the transport infrastructure only have initial benefits in areas where accessibility is limited, but in areas with well established transport infrastructure they provide much less of a benefit (Boarnet, 1997). The external costs of transport are thus of crucial importance due to the tragedy of commons effect it inflicts[18]. Fiscal regulations to address this issue (such as road pricing) are not based on anti-automobile ideals either, but could become a necessary addition when market forces are not capable of adjusting the price of transport to its actual costs for society. Putting limitations on car usage is usually viewed as detrimental to economic growth, but promoting a more diverse transport system can in fact stimulate economic growth (Newman & Kenworthy, 1999).

[18] See section 2.5 for further elaboration on the term 'tragedy of the commons'.

The purpose of this section has been to illustrate the problems that transport causes for society, and how a continuation of current trends will enhance these problems. Both modal switch and demand management strategies should thus be implemented to reduce these effects. However, even combined with new technology they do not seem to offer sustainable mobility, and as such we might need to rethink the source of actual growth in transport and consumption in general: the premise of continued economic growth.

6.2 The folly of growth

As I have tried to illustrate throughout this report there does not seem to be much promise for any decoupling of economic growth from environmental impacts taking place in the near future (at least not for the transport sector), even if proponents of ecological modernisation and the environmental Kuznets curve claim that salvation is right around the corner through innovation and progress. But who is to blame for the apparent lack of decoupling that is taking place? Is it unscrupulous industrial tycoons, who care only for cash profit and laugh at the environmental consequences of their actions? Is it cowardly and short sighted politicians, who fear losing their voter support by making unpopular decisions? Is it apathetic consumers, who would rather support a child in Africa to ease their conscience than reduce their spending on goods and services? Or is it simply that the concept of growth is so incompatible with the concept of sustainability, that achieving the desired decoupling effect is an impossibility theorem in itself?

The Brundtland report (WCED, 1987) was probably a turning point for putting sustainable development on the political agenda, and in it a growth rate of 3.5% annually is advocated for industrialized countries. This equals a doubling of consumption every 20 years; the same timeframe that the Kyoto protocol sets for an 8% reduction in emission of greenhouse gases. It is now clear that Kyoto targets will not be met in 2010, but if we cannot manage an 8% reduction over 20 years how can we then hope to continuously cut emissions in half over the same timeframe in the future? This will be a requirement to make the advocated growth rate from the Brundtland report sustainable. It is clear that development so far has been anything but sustainable, and in the more than 20 years that have now passed since sustainable development became a buzz word we have not managed to make much of a difference. Not even in Norway, the place where Gro Harlem Brundtland became prime minister, has the vigorous devotion to sustainable development resulted in any decoupling of economic growth from environmental impacts; neither in terms of CO_2, energy consumption or ecological footprint (Næss & Høyer, 2009). Scandinavian countries are usually praised for their focus on environmental concern, but not only Norway has failed to achieve a decoupling of economic and adverse environmental impact growth rates. Denmark, Sweden and Finland are still stuck in what Tapio (2005) refers to as 'weak decoupling' of CO_2 and GDP, meaning a small relative decoupling but not an absolute one. In terms of freight transport Denmark is even categorised as having 'strong negative decoupling' (Tapio, 2005), which means that the volume of freight related transport is currently increasing faster than GDP. The European 'best case examples' have so far managed growth, but without sustainability.

To further illustrate the massive reduction requirement to reach a decoupling I have chosen to include the results from four scenarios made by the UK Sustainable Development Commission (SDC, 2009), which can be seen in figure 14. The first three columns represent the current carbon intensity level[19] in three different developed countries where the last four columns represent the four scenarios. Scenarios one and two assumes current economic growth trends towards 2050 with a world population of 9 and 11 billion respectively, which is also the range of the expected population peak presented at the Beyond Kyoto conference in Århus (Denmark) 2009 by Sir David King in his opening address. Scenarios three and four equal income distribution to remove poverty in developing countries and represent low estimates of population growth, but where the entire world population is to meet EU 2007 income standards with 0% and 2% annual growth towards 2050 respectively. Note that none of these scenarios are assuming exaggerated estimates for growth; they are all based on current trends. To meet the ppm goal for the least impacting scenario (1) we would need an annual reduction of CO_2 emissions per unit of economic activity by almost ten times the current level (SDC, 2009). Now, I do not consider myself overly pessimistic, but surely expectations of speeding up annual efficiency improvements by a factor of 10 have to be slightly naive. Furthermore, the two latter scenarios (3 & 4) clearly show that providing equal conditions of living for everyone through continued economic growth is completely unrealistic in regards to any useful definition of

[19] Carbon intensity is here defined as CO_2 emission per unit of economic activity (dollars in this particular case). It seems a relevant unit to include as it can be considered the equivalent of the technology measure T in the E=P·A·T model from section 1.4, where E then would be carbon dioxide emissions and A would be income per capita.

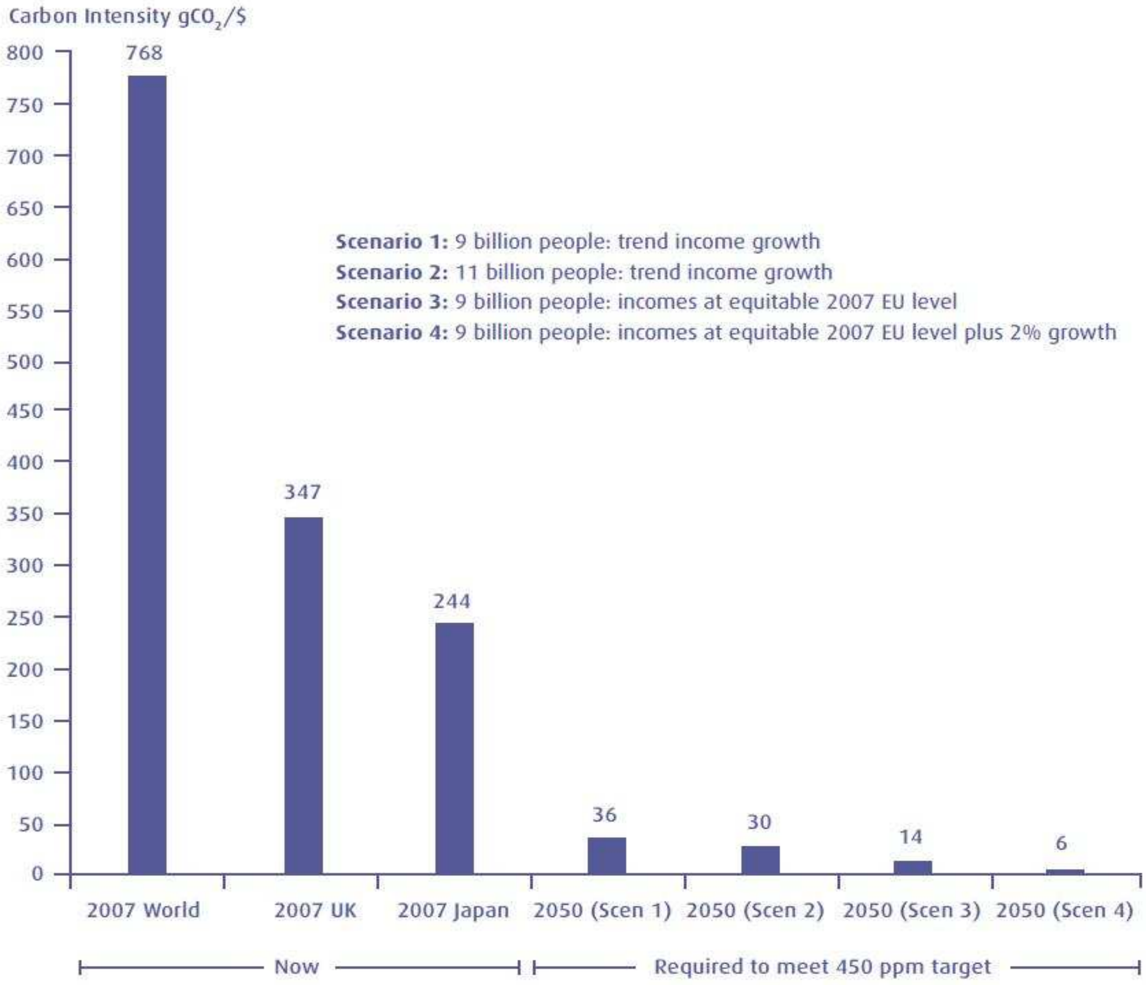

Figure 14: Required carbon intensity levels in different growth scenarios to meet the 450 ppm target of the Stern report (SDC, 2009).

sustainability; achieving equity, sustainability and economic growth at the same time is a utopian ideal we cannot obtain. Noble by intention, but devastating in practise as it traps us in a downward spiral of increasing consumption which cannot be sustained. Not towards 2050, and certainly not beyond.

If economic growth is unable to provide equal benefits for the world's poor then what is the purpose of it? Does it make our lives any better to be richer? I have picked out a few results from SDC (2009) that illustrate how happiness, education, infant mortality rates and life expectancy at birth are related to GDP (PPP), which are illustrated in figures 15 to 18.

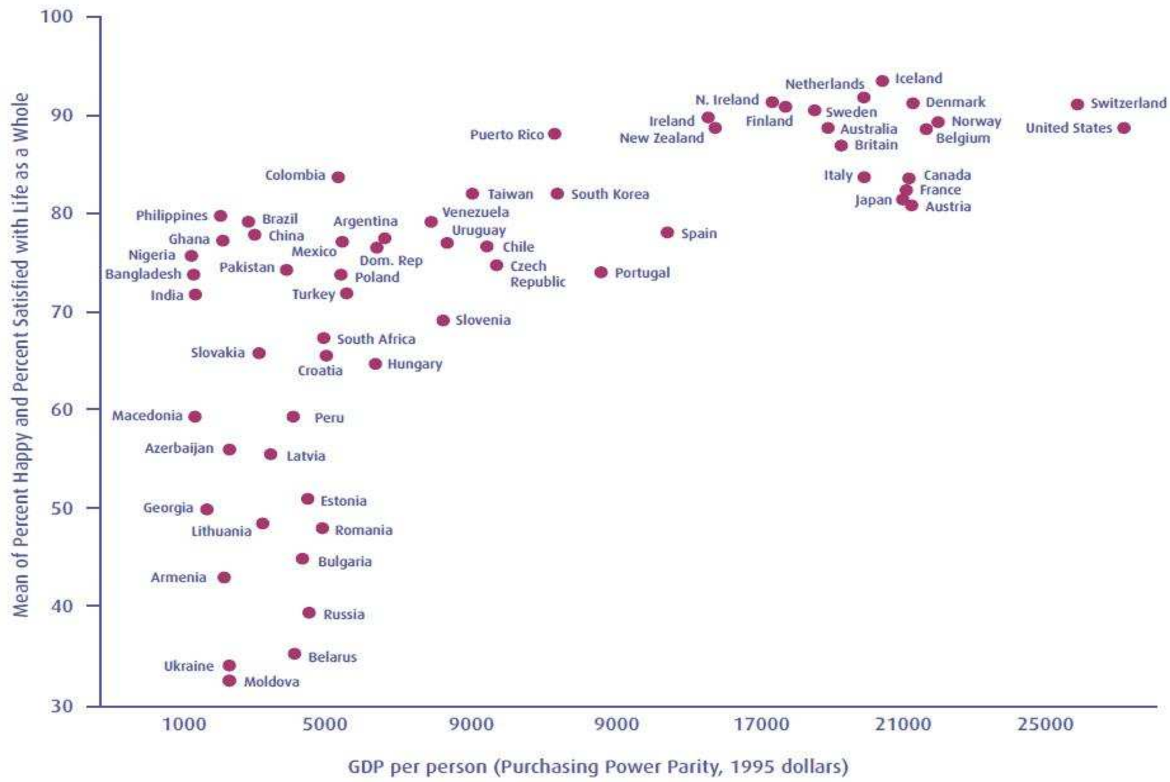

Figure 15: Happiness index compared to GDP (SDC, 2009).

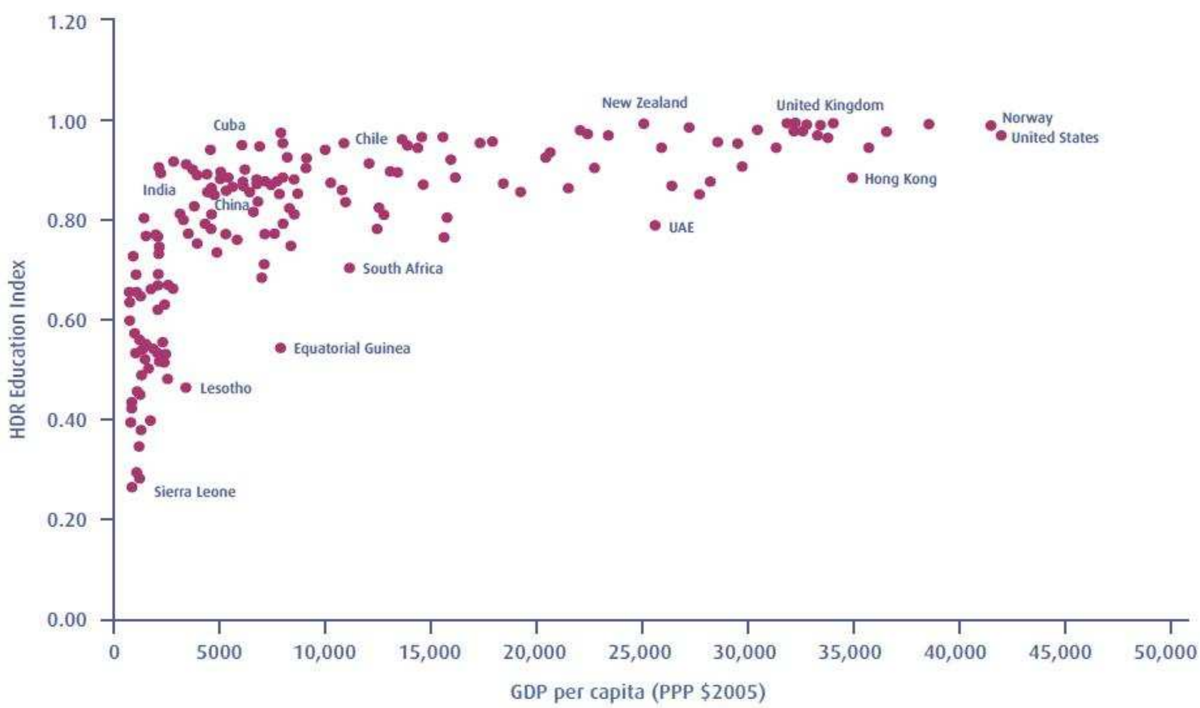

Figure 16: Education index compared to GDP (SDC, 2009).

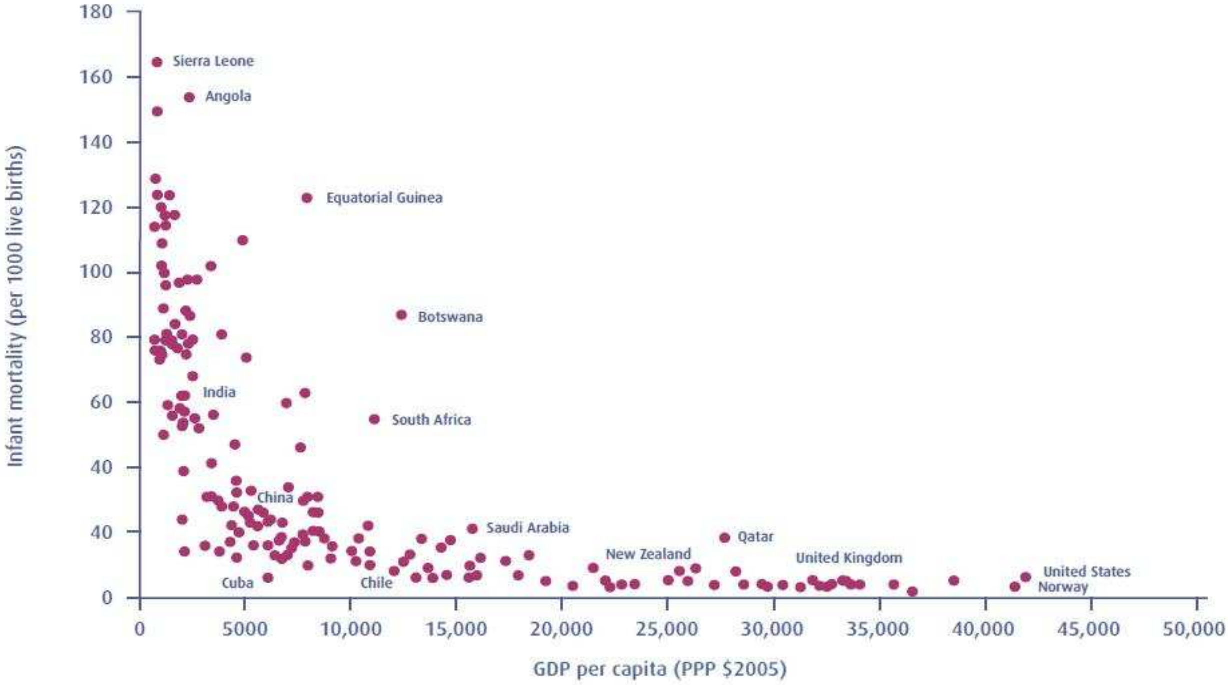

Figure 17: Infant mortality rate compared to GDP (SDC, 2009).

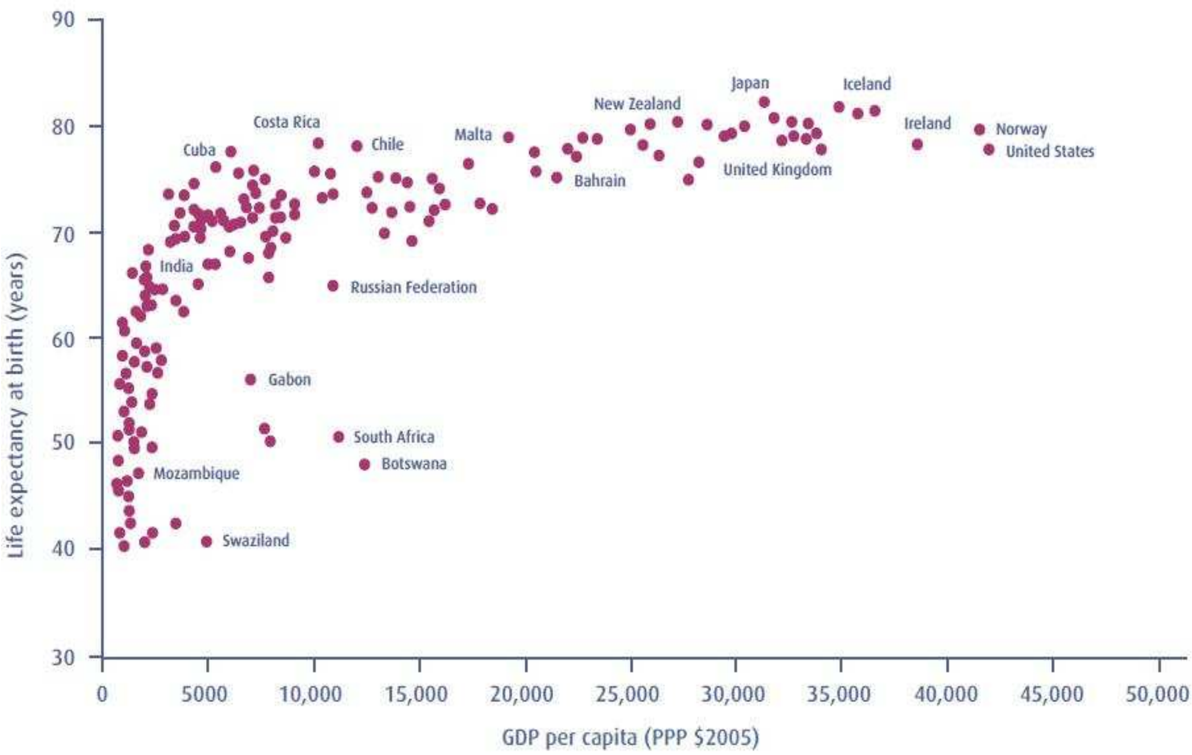

Figure 18: Life expectancy compared to GDP (SDC, 2009).

What we can see from figures 15 to 18 is that increases in GDP do indeed seem to affect both physical and mental wellbeing as well as the level of education. However, a more important observation is that as GDP reaches a certain level the benefits start to slow down drastically with further GDP increase. The trend is very consistent, and the few outliers are usually supporting this argument even further, as they tend to be countries with a relatively large GDP compared to their neighbouring countries, but with little or no improvement in health or education compared to these[20]. It would thus seem that there is a lower threshold for GDP per capita that countries need to sustain in order to reach decent standard of living, but above that threshold further economic activity has little impact on the wellbeing of the country's population.

6.3 Comedo ergo sum

From the scenarios in chapters 3 to 5 I would have to conclude that sustainable growth seems unattainable for now. From figures 15 to 18 it seems that growth in economic activity does not seem to significantly improve people's lives either. The obvious question would then be "*why don't we stop growth until we reach a sustainable level?*" Simply put, the economic system that we have today would never survive a static economy. Advances in technological efficiency is required to produce more output from whatever input we have due to increased resource scarcity, which in turn results in lower production costs. However, it also means that less labour is required to produce that output, so the gain in economic activity from an efficiency improvement has to be equal to or higher than the gain in labour productivity. If economic growth slows down it means that some people lose their jobs, which is what we are witnessing in the current recession. Unemployment is quickly accompanied by reduced spending and demand reduction, and while it certainly reduces resource use and emission levels when this happens, it should be obvious that this is not a desirable approach to sustainability for any market. Economic growth thus becomes the single most important aspect of governments around the world. A growth based economy stabilises through further growth, but as growth is not sustainable this leaves us in quite a dilemma. Growth in its current form is not sustainable, but de-growth under current conditions is not stable.

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[20] One such example would be Botswana, which has often been named 'the African Miracle' due to its rapid economic growth that is somewhat of a rarity in sub-Saharan Africa. The GDP growth stems mainly from the country's massive diamond industry, but as is evident from Figure 15 this has not resulted in a similar dramatic increase in public health standards, perhaps mainly due to the large number of HIV positive people living in the country an poor management of resource incomes.

Apart from providing stability in the financial system, economic growth and increased demand for material goods also seem to reflect a fundamental trait of human nature. René Descartes' renowned expression 'I think, therefore I am' seem to have morphed into a less flattering version of 'I consume, therefore I am'. Consumer goods are not only acquired for their function but for their communication value as well (Bauman, 2007; Dittmar & Pepper, 1994; SDC, 2009). We use material goods to reflect status, personality and success, and we do so to compare with the people that surround us. The level of comparison income is perhaps more important than the individual income level, as if we find ourselves lacking we start envying those who reflect a better standard of living through their material possessions (Belk et al., 2003; Ferrer-i-Carbonell, 2005). The effect seems similar to that of the psychosocial benefits of owning and driving a car that were mentioned in section 4.4, which constitutes a barrier for motivating people to use public transport. From the results of Belk et al. (2003) it would seem that motivating people to reduce consumption in general can be quite difficult as well, which is not a unique trait of modern, western societies as one might initially suspect: "*The symbolic role of material commodities has been identified, by anthropologists, in every single society for which record is known*" (SDC, 2009: 39). So, while economic growth might increase the total amount of wealth, much of the gains in regards to individual well-being are lost to positional competition. We thus find ourselves in yet another dilemma of economic growth, as continued economic growth of a country in itself doesn't add to individual wellbeing or happiness (when growth is unequally distributed it would in fact diminish it for some), but slowing down growth would mean that comparison income drops in relation to surrounding countries. Either way the pursuit of increased opulence does not result in any increase in individual well-being, unless it can somehow serve to even out differences in individual income levels.

6.4 Capitalism is dead; long live capitalism

So far I have argued that a decoupling of economic activity and environmental impacts is seemingly not taking place and is unlikely to do so in the future, which makes the premise of economic growth a fundamental factor of insustainability in our current economic system. Furthermore, growth is required to offset efficiency increases from technological advance to keep up labour demand as labour (along with natural resources) is still the actual source of economic activity, making de-growth an undesirable approach as it causes instability due to a rampant unemployment increase. A requirement of continued economic growth coupled with a consumer base, which has a desire to possess increasing amounts of material goods e.g. to reflect social status and sense of place, forms a strong alliance, that continuously reinforces the demand for an expansive economy. In traditional neoliberal economic theory this coupling would symbolise a positive feedback cycle to keep the economic engine running indefinitely, but if ecological modernisation, green capitalism and dematerialization strategies do indeed prove unsuccessful in providing a decoupling of economic activity from resource consumption and environmental degradation, this engine will come to an abrupt halt at some point due to the finite nature of the ecological system that is Earth. What I have tried to illustrate throughout this report is that there is no convincing empirical data to suggest that such a decoupling is taking place, and the scenarios in chapters 3 to 5 do not offer much hope for decoupling in the transport sector in a foreseeable future.

The dilemma of growth thus seems a dire one indeed. Either growth will eventually reach a natural limit, enforcing a recession far greater than what we are currently witnessing, or we will have to abandon growth and cause severe degradation of living standards for millions of people. However, just because the problem at hand is a difficult one it would do us no good to ignore it, and in this section I will try to explore a few of the options that could help facilitate a smoother transition to a new economy. It should be noted that I am not an expert of any kind in matters of macroeconomic forces, and combined with a general lack of available literature on how to model a system with no economic growth, the thoughts presented here should likely undergo intense critical scrutiny before inclusion in the economic growth debate. The apparent lack of previous exploration into this field only makes the challenge that much more interesting though, as it would seem that capitalist ideals pervades economic theory, policy making and the general public without being questioned (and in the event that it does one is likely to be labelled as a communist). However, as this is a topic that ought to be explored more thoroughly in another project, I will only briefly present a set of suggestions for how to move from contemporary capitalistic economy to a more sustainable one.

6.4.1 Better indicators of prosperity

The first point I would like to address is how prosperity is measured. Prosperity here is taken to mean something more than a measure of one's opportunity to indulge in material consumption, and is perhaps best defined in the words of Tim Jackson in the foreword to the report from the 'Prosperity without growth' project: "*Prosperity consists in our ability to flourish as human beings – within the* *ecological limits of our planet"* (SDC, 2009: 7). While this definition surely allows for some interpretation, it reflects my perception of the term rather well I think. The end goal of all progress ought to be an improvement of the quality of life rather than the quantity of it, and while the intention of pursuing continuous economic growth might very well be to improve the quality through quantity, it is certainly not always the resulting outcome as we saw in figures 15 to 18. Despite steady economic growth in most OECD countries from 1980 to 2000, only very few of them have managed to reduce income inequality and poverty, while many have managed to increase income inequality and even more have managed to increase poverty (OECD, 2008)[21]. Economic growth measured in GDP thus seems a very insufficient measure of real progress in terms of prosperity, as the benefits are benefiting those who already have the more. Globally this means that developing countries, of which some are in dire need of a more prosperous future, are reaping the least benefits and perhaps even paying the costs of increased wealth in the developed world. In developed countries it means that the increase in wealth does not manage to increase the wellbeing of large portions of the population due to positional income effects.

These inequalities, along with the degradation of natural resources and criminal activities, are just some of the things that GDP as a measure fail to take into account, and on top of that GDP is actually increased by a number of very undesirable activities such as oil spills and car accidents, making it even less suited as a measure of human wellbeing (Cobb et al., 1999; Gilbert & Nadeau, 2001; SACTRA, 2008). It is no wonder that GDP is such a poor measure though, as it was "*designed as a planning tool to guide the massive production effort after World War II [...] it was never intended as a yardstick for economic progress; yet, gradually it has gained totemic status as the ultimate measure of economic success*" (Gilbert & Nadeau, 2001: 9). Hicks (1946) argued that the purpose of calculating income is to indicate the maximum production achievable without undermining the capacity for such production in the future, and as GDP does not reflect issues of deterioration very well we then ought to seek new measures that does. The Genuine Progress Indicator (GPI) is an example of another monetary measure that is based on much of the same data that is included in the GDP measure, but adjusts it for factors such as income distribution, community work, crime, resource depletion, leisure time, lifespan consumer durables, dependence on foreign assets, etc. These factors are among the

[21] Income inequality is here measured by Gini-coefficients, poverty by headcount rates.

ones we would like to actually change in order to prosper as human beings, and such a measure thus seems a lot better suited to indicate the progress of a nation than does GDP.

6.4.2 Reversing consumption culture

As argued in sections 4.4 and 6.3 people's desire to consume resources through various activities or acquisition of goods seem to a fundamental human trait. The consequence is very visible in modern western societies with resource consumption skyrocketing, problems of obesity related diseases escalating and spiralling recession when production fails to keep up with expectations. Growth in itself simply isn't working as intended. The way it is currently structured has negative physical, psychological and social impacts, and instead of progress and prosperity we are left with recession and disparity. Consumer culture results in less durable products, as the required lifespan is greatly reduced, when people acquire new versions and dispose of old models multiple times per year, and commercial media encourages further consumption to signal status, personality and belonging. Advertisement is also targeting consumers at an increasingly younger age, which further enhances the consumption mindset for future generations, and the possibilities for stronger regulation on these sorts of activities should be fully explored to reverse the growing consumerism we are witnessing. We generally believe advertisements to be trivial and repetitive, and thus are less critical towards the effects they have on consumer culture (Dittmar, 2007). It enforces a culture in which we do not only seek to purchase and consume increasing amounts for the sake of obtaining material goods, but where consumption itself is aimed at creating identity and fulfilment for individuals (Bauman, 1998; Kilbourne, 2006). It's been 45 years since Beatles tried spreading the word of "C*an't buy me love*", but while the song's musical qualities transcend borders, age and social class, the message of reduced obsession with material wealth has not had the same success it would seem.

In light of Foucault and his power analysis we are here witnessing a subtle control of the individual through norms of modern western societies. This control is not enforced physically through overt oppression, but rather through a willing acceptance of a set of norms and standards from the subjects of control. When growth permeates the very concept of normality it is no wonder that consumption is spiralling out of control. This drive towards acquisition of goods and use of resources need to be reverted if we are to achieve a sustainable environment. Slowing down, not only in traffic, is a prerequisite for any society that aims at sustainable development.

6.4.3 Limitations on resource use and emissions

Defining an exact, quantifiable limit for the entire earth's ecosystem is no easy task, and I am not sure that the accuracy of the calculations involved is the most important aspect in defining ecological limits. What is important is first and foremost to change the structure of our society to one that acknowledges that finite boundaries do in fact exists. At the moment economic growth completely overshadows this goal in modern societies across the globe, due to the totemic stature it has in the current structure. This results in economic growth becoming priority number one, and abating adverse environmental effects must then be adapted to how this growth can be upheld. Sustainable development requires a reverse order of priorities here, which can be done by imposing clearly defined caps for resource use and associated emissions, so economic activity is enclosed by the ecological limits on which it relies. Adverse environmental effects can no longer be considered externalities or an unintended side-effect of growth. Not only are they undesirable, but they are also reducing the potential capacity of ecosystems in the future, and are thus in direct opposition to progress in a long term perspective, no matter what definition of progress is used.

Sustainable development theories such as ecological modernisation, green capitalism and dematerialisation have so far failed to reduce these effects. Not because they have not achieved any reductions in per unit resource demand (although some in fact have had the opposite effect), but because growth accelerates beyond the scale of these reductions. As illustrated throughout this report, the amount of reduction required in 20, 50 and 100 years goes far beyond sanity, and eventually consumption culture will cause an ecological overshoot, as in any other ecosystem where resources are limited and consumption is increasing exponentially. These are not apocalyptic prophesies but merely the arithmetic of growth at work. A sustainable economy would instead identify how many available resources we have to use and then adjust the economy accordingly, much like doing a household budget on a grand scale. If you spent above your budget you will end up in debt, but so far we do not know for certain what Mother Nature charges in interest. To avoid bankruptcy we are thus best advised to stay on budget.

Jespersen (2004) and Daly (2008) both suggest regulatory instruments for putting ecology before economy, and both of them advocate a cap-and-trade system. Daly refers to a trading system for emission permits similar to what is currently in its infant stage for CO_2 trading, while Jespersen refers to a trading system for work permits. The shared goal of their visions is a stable economy that doesn't lead to rising unemployment, require us to live under communist tyranny or start painting instructions for how to slay a mammoth on cave walls. Instead of increased labour productivity causing unemployment it could allow us to work fewer hours. The job of economists would thus shift from ensuring economic growth to ensuring economic stability. Another main mechanic to promote a steady state economy is taxation, but a much more drastic change that current 'green taxes' have been. Daly goes so far as to suggest abolishing income tax altogether (hardly a problematic idea to sell for politicians) and instead tax resources at the point of extraction, as this would encourage a better value-adding chain. These suggestions seem radical to conventional economists, but they are fairly easy to implement on a technical level. The main barrier is a global commitment to such a system, as it could only work if no one is left to exploit the resources outside of this system. Problems of regression can be avoid through structural changes within the system, either by funding benefit programmes from resource taxes or by making a progressive taxation system, that scales with consumption. This would allow basic needs to be fulfilled while punishing excessive use of resources. The idea of steady state economy is however struggling against a 200 year old tradition of economic growth, but even one of the founding fathers of classic economic theory, John Stuart Mills, foresaw the necessity of it when economic growth would reach a certain point, and hopefully the economists of our time will as well:

> *"It must always have been seen, more or less distinctly, by political economists, that the increase of wealth is not boundless: that at the end of what they term progressive state lies the stationary state, that all progress in wealth is but a postponement of this, and that each step in advance is an approach to it. [...] It is scarcely necessary to remark that a stationary condition of capital and population implies no stationary state of human improvement. There would be as much scope as ever for all kinds of mental culture, and moral and social progress; as much room for improving the Art of Living, and much more likelihood of its being improved, when minds ceased to be engrossed by the art of getting on. Even the industrial arts*

might be as earnestly and as successfully cultivated [...] Only when, in addition to just institutions, the increase in mankind shall be under the deliberate guidance of judicious foresight, can the conquests made from the power of nature by the intellect and energy of scientific discoverers, become the common property of the species, and the means of improving and elevating the universal lot."

Mill (2003: B. 4, C. 6, p. 877 ff.)

7 Conclusion

"The automobile works honestly. Long before its birth, when it is still just layers of metal and piles of drawings, it diligently murders Malayan coolies and Mexican laborers…It shreds flesh, blinds eyes, eats lungs, destroys minds. At last, it rolls out of the gates into the world which, before its existence, was known as 'bright'. Instantly, it deprives its supposed owner of his old-fashioned piece of mind… The automobile laconically runs down pedestrians. It gnaws into the side of a barn or else, grinning, it flies down a slope. It can't be blamed for anything. Its conscience is as clear as Monsieur Citroen's conscience. It only fulfills its destiny: It is destined to wipe out the world."

Ilya Grigoryevich Ehrenburg, 'The life of the automobile' (1929)

7.1 A quick summery

The general aim of this study was to provide some insight into the decoupling potential of economic growth and environmental impacts by investigating recent experience from the transport sector. The purpose of doing so was to evaluate a set of common strategies employed by policy makers and planners alike, in order to recommend which of these would be most desirable from a societal perspective and most appropriate in terms of sustainable development. The motivation for doing so has primarily been the growing evidence of anthropogenic causes to environmental impact and climate change, of which increasing transport demands constitutes one of the biggest challenges.

A backcasting approach to the scenario construction was chosen in light of the need to change the complexity of the sustainability discussion and the general undesirability of current development trends. Apart from investigating the decoupling potential of the strategies employed in each scenario, a discussion of societal consequences of pursuing these strategies has also been included. The results from all three scenarios indicate that a potential for quite large reductions does indeed exist, but also that the pace of which change is taking place is far below the requirement to successfully decouple transport from its environmental effects, even if their reduction effects where to be combined. In figure 19 I have combined these effects to illustrate that a sizable potential reduction is possible, but also that it will still be eaten up within a few decades. Note that this is a very best case scenario in which a 20% modal switch has successfully taken place, all new construction is done in line with compact city principles, road pricing is implemented and the most optimistic of recent forecasts for implementation of electric vehicles is used[22].

In addition to this some of the strategies are likely to enhance positive feedback mechanisms that support unequal distribution of benefits and costs of transport activities. In conclusion the scenarios illustrate how important it is to focus attention to all of the instruments used in them, as their combined effects could offer great reduction potentials. However, a more important conclusion is that even the cumulative reduction effect of these scenarios would hardly be enough to achieve sustainable mobility in the long run.

[22] Forecasts are from Concito (2009) and electric vehicles are assumed to be powered by 100% CO_2-neutral energy sources.

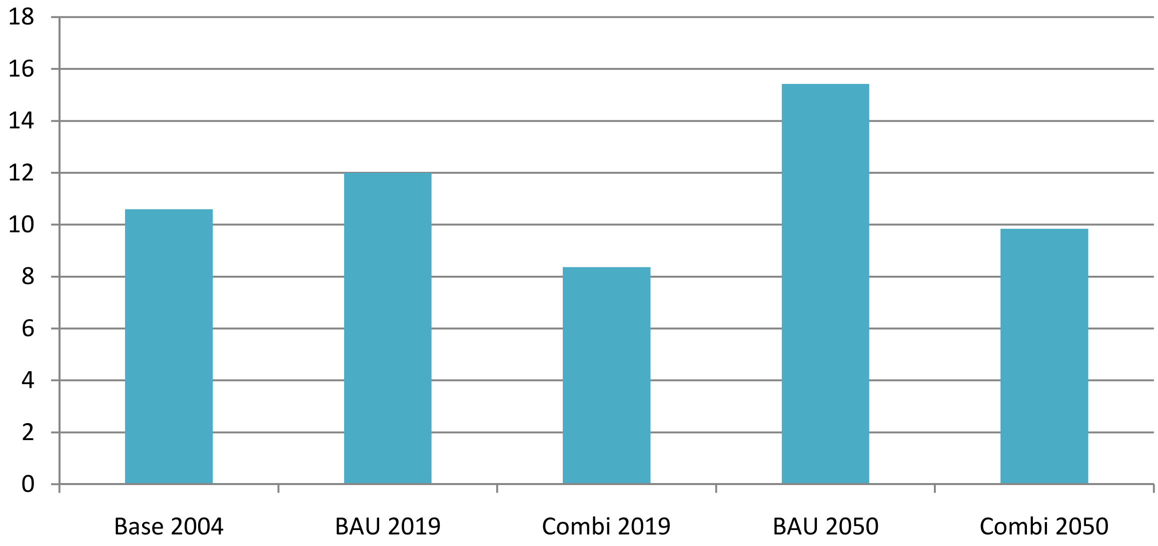

Figure 19: Estimated development in CO_2 emissions (mil. ton) from passenger transport if current trends continue (BAU), and if a combination of the results from chapters 3 to 5 are implemented (Combi). 2004 is chosen as reference year due to availability of datasets from the three scenarios in this report.

The discussion based on the results of the constructed scenarios thus did not only involve a comparison of the environmental and societal consequences of each scenario, but stretched into questions of whether the fundamental idea of economic growth in its current form as the primary rationale for policy making, planning and society at large is reasonable. Data from a range of different countries across the globe indicate that bigger isn't always better in terms of opulence as a measure and instrument of improving the wellbeing of a society, both for the population as a whole and for the individual citizens. As growth in the consumption of material resources cannot continue due to ecological constraints, and as we seem unable to decouple it from encroaching further on fragile environmental grounds, it does then both seem relevant and necessary to look for ways to change the existing structure, and as such the recommendations for a future structure culminated the sustainability discussion of the previous chapter.

7.2 Beyond growth

If we continue consuming the worlds resources at current pace we will force a global collapse of both economy and environment at some point, and so far the optimistic theories of ecological modernisation and the like have proved insufficient in slowing down the thrust forward. For the transport sector this is evident from the continued coupling between economic activities, transport volumes and environmental impacts that we are witnessing, and if the results of the scenarios in this study are indeed correct, there is no immediate decoupling to be expected in the next decades from neither technocratic fixes, modal switches nor conventional demand management. Their efforts will surely help, there can be no doubt about that, but if these are the only areas in which we pursue solutions, then the result will only be to worsen the situation by giving a false sense of security, while the real problem goes unnoticed.

Enthusiastic proponents of ecological modernisation would argue that the benefits of growth needs time to settle in and trickle down through the different layers of society, but there are two main points of critique against such a position. First, as has been illustrated numerous times throughout this report, growth rates vastly outweigh reduction rates, and have so far eaten up any absolute decoupling. Relative decoupling, while a necessity as well and a step in the right direction, simply is not enough. Not in a short term perspective, and certainly not in the long run. Second, time is a luxury that we might not have much longer. Unlike problems of social inequity, unemployment or obesity, environmental degradation can only go on for so long before the consequences start kicking in. The time for action is long overdue.

For a large majority of earth's existence its life forms have consisted of single celled organisms, and if this is the state of equilibrium it returns to when stressed enough, all the sustainable energy that we can conjure up at some point in the future won't be of much use. Now, things hopefully will not end up in such a doomsday scenario, but slight changes are all that is needed for us to be in a lot of trouble. Mother Nature is surely a tough nut to crack and will adapt fairly well to a range of quite dramatic ecological changes, but humankind is much more fragile and not necessarily part of such adaptation. Rising temperatures, polluted soils and global water shortages are just some of the consequences we are witnessing from our consumption. We have become fixated with economic growth and obsessed with quantifying performance. An elite of politicians and economists from the developed world have blackboxed the idea that growth is the solution to unemployment, inequality and poverty, while scientists are (unsuccessfully) trying to construct a setting in which this would actually be the case. Conventional wisdom needs to be challenged, and instead of focusing on opulence we should focus on prosperity, as exemplified by this citation from a recent New Economic Foundation report on growth:

> "*In the growth debate, for all its theoretical sophistry, orthodox economics invariably falls back on a few tried and tested metaphors to defend its growth obsession. Either we are told that a rising tide lifts all boats, or that, rather than sharing the cake more evenly, it is better to bake a larger one. Ironically, however, at the time of writing, sea levels really are rising, as a result of global warming, itself driven by the pollution from economic growth. And the problem is that millions more of the poor have no boats to rise in, while millions more have boats which are not seaworthy, and are also likely to drown in a warming world. As for the cake, even the massed ranks of orthodox economists are yet to find either the recipe or the ingredients to bake a spare planet to share among the world's population.*"
> (NEF, 2006: 25)

The concept of sustainable mobility needs to be viewed in this larger context of sustainable development. The conclusion of this study must be that concept sustainable development is not compatible with the otherwise popular concept of sustainable growth, and as such economic growth is not compatible with sustainable mobility either, as it cannot be decoupled from its adverse environmental effects. The expansive nature of growth has traditionally been able to expand into new territory to grow further, but as we reach the ecological limits of earth's resources there is no bridge at the end of the world leading to new territories. It has taken all of human history to accumulate the wealth we have today, but in two or three decades it will have doubled. The growth problem can be perceived as a bacteria colony in a petri disc doubling its population size for every generation. At generation x there is 15/16 of the resources left. At x+1 there is 14/16 left, at x+2 there is 12/16 and at x+3 the colony has used up half of the available resources. The next time it doubles it will have used all available resources, and the 'society' will collapse. The general concept is the same for our resource use, and while it has taken thousands of years to reach our current consumption we are faced with the same problem as the bacteria colony: doubling the economy twice could mean going from plenty of resources to complete exhaustion. To conventional economists this is blasphemic and heretic accusations, but for scientists it is the conclusion of simple arithmetic. It ought to be for anyone else as well.

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