Preface
This report, which has been prepared by Profu in co-operation with the Chalmers University of technology, provides an overview of the transport sector and examples of how the transport sector in the local setting could be changed in a more sustainable direction. Even if the stationary energy system is the main focus of PATH-TO-RES, there are several linking possibilities that can contribute to an increased level of sustainability.

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1 Introduction

The main purposes of this report are to:

- Perform a discussion of the context of the transport sector and the possibilities of a more sustainable transport system at the local level.
- Provide recommendations (as far as possible) for identification and evaluation of “sustainable transport measures” in a local system.
- Serve as a guideline to case studies in the upcoming work and as input to the development and assessment of the 7-step checklist later on.

The six case studies and the experiences made from them this far is an important foundation for the items above. The report has been divided into the following sections:

1. Introduction
2. Overview of technologies and measures
3. Examples of projects and actions
4. Alternative fuels from a systems perspective
5. Summary of key aspects

In some contexts this report builds partly on the previous reports D3.1 “Technology assessment methodology”, and D3.2 “Methodology for efficiency analysis”. Some of the suggested evaluation criteria for different technologies and efficiency improvement measures are also appropriate in order to evaluate transport measures from a technical perspective. However, there are a number of further aspects that must be considered for measures and actions in the transport sector, in particular the fact that a large part of the transport work could consist of transports just passing through the area for which the planning is done and that there is little possibility for direct control of the development by the municipality.

As for the D3.1 and 3.2 reports, the ambition is that the major parts of the evaluations and discussions described in this report should be applicable without expert knowledge of any kind. Furthermore it is concluded (as in all other contexts of Path-To-RES) that a description over the present energy system, including structure and data, is a pre-requisite in order to identify and evaluate efficiency measures in the local setting. Without this knowledge over the present system it cannot be concluded what consequences a certain efficiency measure will have on other parts of the system. For the transport sector the input data for such a description may be difficult to find. However, the importance of the development of the transport sector is very large and therefore this difficulty should not be taken as a reason for not including improvement of transport from a sustainable point of view in the pathways/roadmap.

In this paper we have concentrated on presenting examples of options that are available in order to develop the transport system in a sustainable direction.

2 Overview of transport alternatives

The transport sector, the possibilities of local influence over the development and its relation to the stationary energy system in the local setting can be briefly characterized in the following points:
A large part of the total energy use is related to transport. Globally 28% of all energy is used in the transport sector [4]. In the EU-27 the transport sector accounted for about 31% of final energy consumption in 2005 [5]. Emissions of CO\textsubscript{2} have been decreasing in all main sectors in Europe during the last decade with an exception of the transport sector, emissions of which instead have been increasing and is most likely to continue to increase [6]. Road transport constitutes the largest emitter of CO\textsubscript{2} in the transport sector, accounting for approximately 90% of the emissions. Previous and current EU policies have mainly focused on improving vehicle technology and fuel quality to reduce emissions from the transport sector [7]. However, trends and projections show that despite introduced mitigation measures the intended effect has not taken place, largely due to a continued increase in transport demand [6, 7]. The road transport sector, which accounts for over 80% of final energy consumption in the transport sector [5], is totally dominated by fossil fuels (gasoline and diesel oil) [8]. These fuels are produced in refineries that operate on national or international markets. The vehicles that are available are designed and produced for an international market. There is consequently very limited influence on the development from the local level.

Alternative fuels are in various degrees available locally, but they have presently very limited market penetration [9]. Examples of such alternative fuels or energy carriers can be natural gas, hythane\textsuperscript{1}, hydrogen, ethanol, biogas, FAME and electricity. There are however ambitions at local, national and EU level to increase the shares of biofuels and therefore their market share can be expected to increase rapidly. The directive on the promotion of the use of energy from renewable sources includes a 10% binding minimum target for biofuels in transport, which should be achieved by each Member State in the EU by 2020 [3]. Most alternative fuels are produced for a national or an international market. Biogas is however a fuel that is often produced locally [10]. A specific kind of electricity driven vehicles are trolley buses for public transport in densely populated areas. The electricity is supplied by means of a grid system that follows the bus routes. Here municipalities generally have a large influence over the development.

In addition to road transport, significant parts of all transports are also made by means of railway, ships and aircraft. These means of transportation are generally parts of national or international transportation systems with little influence from the local level. Municipalities with harbours or airports may however have different ways of influencing the development in these fields. A specific kind of rail bound transport is trams and subway systems, for public transport in densely populated areas. Here municipalities generally have a large influence over the development.

The municipality has limited influence over the development of the transport system. Most decisions are made on the individual level, by those who transport goods and by the government who decides upon policy instruments. However, there are areas where the municipality definitely could influence the development, e.g. public transport and the municipalities’ own transports. This will be discussed below.

\textsuperscript{1} Hythane is a mixture of natural gas and hydrogen, usually 5-7 percent hydrogen by energy.
3 Examples of projects and actions, in relation to the possibilities to influence at the municipality level

In this section we present examples and discuss how the transport sector could be developed by means of local initiatives, e.g. by the municipalities. We have tried to relate projects and actions to how the development could be influenced from the municipalities’ point of view (“control, act, inform”). The presentation is partly inspired by a publication from the Swedish Energy Agency [1]. A number of other references have also been used. Of these references we especially recommend two publications from the European Environment Agency for readers who want to learn more about the external drivers of transport demand [12] and success stories within the road transport sector on reducing greenhouse gas emissions and producing ancillary benefits [11].

The presentations should not be seen as a complete list of all possible actions, but rather as examples that could be used as source for inspiration regarding the change of the transport system in a more sustainable direction. We also present some examples from the Path-To-RES case studies. In appendix 1 we present transport related examples from the case studies’ 2nd tentative roadmaps.

The vehicle fleet
The municipality and companies typically has a large fleet of vehicles consisting of cars, lorries and sometimes buses. They also use a number of different machines, e.g. tractors, lawn mowers, excavators and compressors. When new vehicles and machines are acquired municipalities and companies have the opportunity to influence the fuel consumption and emissions of the fleet. By choosing fuel efficient vehicles and vehicles designed for fuels with small emissions considerable improvements can be achieved. This possibility is often overlooked.

The municipality can also encourage the inhabitants to act in this way. One way of doing this is to contribute to the improvement of the infrastructure for alternative fuels. Another way of supporting alternative fuels is to offer leasing cars for alternative fuels, e.g. biogas, to employees of the municipality. By doing so the municipality contributes to the establishment of a local market for alternative fuels, thereby making it more attractive for biofuel suppliers. Improved transport planning is also an important measure related to the effective utilization of the vehicle fleet.

Work related travel
Many municipalities and companies have developed policies for work related travel. They often encourage the use of bicycle for short distances. For longer travel they typically recommend public transport and that train should be preferred over air travel. In addition telephone or video conferences should be chosen when possible. When rental cars are used they should be chosen with respect to fuel economy and emissions.

The municipality could also in different ways encourage their employees to use bicycle or public transport when they travel to and from work. For individuals who switch to public transport for work related travels but still want to have the possibility to use a car, car sharing pools could be an option. There are a number of such schemes available in most countries [11, 12].
Society paid travel
The municipality could as part owners in public transport companies and/or as transportation buyers make demands on fuel economy and emissions when transport services are contracted. The municipalities could also contribute to a larger market share for public transport by improving the quality of “the product”. Public transport is often, at least in Sweden, organized regionally, with limited influence at the local level. This could make local ambitions regarding public transport difficult to realize, if these ambitions are not shared by the rest of the region.

Transport of goods
A large part of goods transport seems to be difficult to influence at the local level. But when the local transport is analysed it may be possible to find more efficient logistics solutions, e.g. combined distribution, return cargoes and smart logistics, that could result in both lower costs and less emissions [11]. In order to minimize transports and to reduce emissions in certain areas it is also possible to divide the municipality in different environmental zones, with different demands on vehicles for emission, fuels, etc. (Environmental zones are further discussed in the section “Congestion charging and environmental zones” below.)

Drivers’ behaviour
The fuel consumption is not only a result of the vehicle performance data and the choice of fuels. It is also highly influenced by how the vehicle is driven. An economical way of driving typically reduces the fuel consumption by 5 - 15 % [1, 13]. Changed driving behaviour therefore holds a relatively large efficiency improvement potential.

Many transport companies are aware of this measure and encourage their drivers to become more “fuel efficient” both by means of courses in “Eco-driving” and technical measures, e.g. information from the vehicle computer. The result is both reduced costs and reduced emissions. The municipality can use the same strategy for their own transports [11]. It can also in different ways encourage the inhabitants to drive more economical.

Physical planning
Most travels in the municipality are short. It is work, service and purchase travels. They are to a large extent structurally conditioned, i.e. influenced by how the municipalities’ different functions are localized [14]. To change this structure is a very slow process and it is neither desired nor possible to optimize this only from an energy perspective.

There is however certain areas where the municipality should be especially observant and where far-sighted efforts can influence travel patterns. It could concern the localization of shopping centres and larger working sites [14]. A foreseeing municipal planning could contribute to a reduced demand for transport and to a better and more pleasant environment. Such a planning could e.g. facilitate walking, cycling and public transport.

Congestion charging and environmental zones
Congestion charging and road user charging schemes aim to reduce vehicle use by charging users to pay for entering or travelling in a certain zone. The resulting reduction in vehicle use
both reduces transport congestion and emissions. A congestion scheme has e.g. been in operation in London since 2003. A trial was also recently conducted in Stockholm. Both examples indicate significant reductions in emissions [11].

It is also possible to divide the municipality into different environmental zones, with different demands on vehicles for emission, fuels, etc. An example of the effects of environmental zones is the city of Prague, which has seen a shift towards more environmentally friendly vehicles, a decrease in emissions and energy consumption, as well as a decrease in noise from traffic [11].

Infrastructure for alternative fuels
For those municipalities that commit themselves to facilitating the use of alternative transport fuels this often leads to a responsibility for new kinds of infrastructure. This infrastructure could be of different kinds, depending on which alternative fuel that are considered. It could e.g. be loading stations for electric cars, production, distribution and filling stations for gas (which could consist of upgraded biogas) or filling stations for ethanol for the municipality’s own vehicles.

The responsibility could partly be transferred to e.g. a municipality owned energy company. In the development of such new infrastructure it is important to be clear on where the responsibility ends and which parts of the chain from resources to transport that the municipality could influence.

In the Path-To-RES case studies there are a number of municipalities that are engaged in operation or development of such infrastructure:

- Electricity for trams, trolley buses and subway systems (Göteborg, Gdansk, Valencia, Arnhem)
- Natural gas for transports (Most of the case studies)
- Biogas for transports (Göteborg, but probably some other case studies as well)

Besides the examples above, there are some important development and prototype projects that have been identified within the case studies:

- Hydrogen and fuel cell applications (Valencia, Partner NTDA are involved) (Arnhem)
- Hythane (Dunkerque)
- Co-generated gasification (Göteborg)

Cycling
Cycling is a very effective, clean and cheap means of transport. There is a potential to increase the share of bicycle transport, but only at short distances of up to 5 km [15]. For example, there are cities in Europe where more than 30 % of the residents cycle to work [8, 15]. Since a large part of our travel habits are founded during the childhood and youth period it is important to provide practical and safe travel routes to the children’s and teenagers schools and leisure hour activities [16]. Separated waking and cycling lanes are therefore important. It is of course important to facilitate cycling also for other categories and safe and practical cycling routes should be considered already during the planning stage.
Communication without transport (information technology)
With today’s information technology it is possible to avoid a large part of physical meetings that make travelling necessary. People can instead meet by means of telephone and video conferences, thereby avoiding unnecessary travel [11, 12, 15, 16].

The use of e.g. internet and e-mail has also facilitated the possibility of working (partly) at home. By working at home, work related travel could be avoided [12, 15, 16]. This is a possibility that should be evaluated by municipalities and companies.

4 Alternative fuels from a systems perspective
When alternative fuels are considered it is important to reflect upon how the fuels are produced. Even if the final energy carrier, e.g. electricity or hydrogen is free from CO₂-emissions at the final use stage, the production of the energy carrier may be related to significant emissions of greenhouse gas emissions.

If electricity is used as energy source for vehicles instead of gasoline or diesel it is necessary to look at how the electricity is produced. This electricity production is generally part of a national or even international electricity system. There are several ways of viewing this and there is no general consensus regarding how this should be done [2]. Here follows a list with examples of such principles:

- Marginal electricity (short term or long term): The properties, e.g. CO₂-emissions, for electricity is related to the electricity production which is found on the marginal, i.e. the most expensive production utilized in the system. In many cases this is seen as coal condensing plants, both in the short term and in the long term. For the long term some view gas condensing plants as the marginal production.

- Extended marginal electricity: Here the effects of specific changes in electricity use are the basis for how electricity is viewed. Calculations of the development of the total electricity production with, or without the specific change are performed. The properties for electricity are thereafter calculated as the difference between the two calculations. This principle includes both the operating margin (how the existing system is run) and the build margin (how new power plants are added to the system).

- Average electricity: Here the properties of electricity are related to the average electricity production for the relevant electricity production system. With this principle all electricity use, existing and new, are equally responsible for the marginal production. (For the two principles above new use of electricity is related to the marginal electricity production.)

- Contract related, guarantees of origin, “green electricity”: The properties of electricity are, according to this principle, a consequence of which electricity that is specified in the contract between the supplier and the user. If CO₂ free production is specified, then this specific use of electricity is viewed as free from CO₂. This is regardless of whether the actual response in the electricity production of this added electricity is CO₂ free or not.
• Policy instrument related, e.g. CO$_2$ emission trading scheme: Since more or less all electricity production is included in the EU emission trading scheme and since this system includes a cap for the total CO$_2$ emissions from the plants included in the system some argue that added electricity does not result in any emissions of CO$_2$. Since the cap is constant the emissions related to added electricity production are simply offset by emission reductions in other plants.

As mentioned above, there is no consensus regarding which is the correct principle. It is, however, important to reflect upon how possible new use of electricity influences e.g. the total emissions of CO$_2$. In order to do this it is necessary to choose a principle and through this establish the relevant properties of this electricity, even if the electricity production can be found outside the system boundary of the analysis.

Similar considerations are necessary if e.g. hydrogen is introduced as an energy carrier. Although the final energy conversion of hydrogen is free from emissions of CO$_2$, the production of hydrogen may be connected to significant emissions. If this is not taken into account, analyses may result in sub-optimizations. If hydrogen is produced by reforming of natural gas there may be emissions of CO$_2$ and hydrogen could not be considered as renewable (since natural gas is a fossil fuel). If hydrogen is instead produced from electrolysis of water the properties of hydrogen are decided by which type of electricity production that is used (see discussion above).

Even if alternative fuels are labelled as biofuels and made from wheat, sugar cane, rape seed, manure etc. it may, from a CO$_2$ point of view, be doubtful if they should be calculated as altogether CO$_2$ free. The EU Commission has specified greenhouse gas emission savings for a number of biofuels [3]. The emission savings typically range from 30 to 85 %, depending on biofuel production pathway.

The RES$^1$ diagram is a practical way of illustrating the systems effects of the use of alternative fuels. If the process (e.g. electricity production or hydrogen production) is found within the system boundary the process inputs and outputs will then be described in the diagram. If the process is found outside the system boundary, the input energy carrier will be illustrated and it is then possible/necessary to attach relevant properties to each energy carrier.

### 5 Summary of key aspects

In this section we present a short summary of key aspect related to the role of the transport sector in local energy planning.

• There are a number of reasons why the transport sector is important in local energy planning aiming for a development in a sustainable direction:
  
  o A large part of the energy consumption is related to transports.
  o There are a large number of ways of reducing the energy demand and emissions related to transports.

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$^1$ Reference Energy System (RES)
The development regarding emissions of greenhouse gases, above all CO$_2$, has so far been disappointing.

- From a municipality point of view the possibility to influence the development of the transport sector is limited. This is not a reason for not trying, but instead it is important what means of influence that should be applied for each specific issue. In chapter 3 we present a number of areas where local initiatives are possible. Two important areas with direct municipality control is public transport and the municipalities’ own transports.

- The system dimension is important when alternative fuels are considered. Energy carriers with zero CO$_2$ emissions at the final user stage, e.g. electricity and hydrogen, may have considerable emissions when the whole production chain is included.

- Look at all aspects of transports, i.e. the actual demand for transport, if transport could be changed to more environmentally friendly and sustainable transport alternatives, more efficient vehicles, better fuels, etc.

- Look for bridging technologies/systems. Natural gas could for example be introduced, thereby switching from gasoline with higher specific emissions. The natural gas could in the mid term perspective (10 – 15 years) be switched to upgraded biogas (biomethane) and in the even longer perspective changed into hydrogen from renewable sources. Electricity is another bridging technology/system. Even if electricity production at present may be associated with rather large emissions there is a trend that the production becomes increasingly cleaner, e.g. through the use of different policy instruments. Electric cars will consequently become better and better from emissions point of view.

- Even if resource management and emissions of greenhouse gases may be the focus for the pathway towards sustainability, it is important to be aware of, and to deal with other emissions and externalities related to transports. For the local environment emissions of NO$_X$ and particles are a large problem in densely populated areas. Noise is also a large problem.

- The following up and evaluation of the local targets regarding the development of a more sustainable transport system is of great importance. One way of doing this is to define and use indicators. Examples of indicators could be the number of yearly public transport travels, how many people use bicycle for work related travel, which fraction of municipal vehicles that use biofuels, the number of filling stations that offer biofuels, etc. The use of indicators makes it possible to perform quantitative evaluations of how successful the decided actions have been.
References


2. Sköldberg H, Unger T, Effekter av förändrad elanvändning / elproduktion – modellberäkningar, Elforsk rapport 08:30, 2008 (in Swedish, summary in English)


Appendix A – Examples of transport related analyses and measures from the case studies (2nd tentative roadmaps)

**Dunkerque**

The Pathway is based on the Grenelle Environment Forum held at the end of 2007 at national level and the development of existing actions at local level.

The strategy is threefold, with one item focused on transports: Changing the transport strategy with priority going to rail and waterway transport. Furthermore, special emphasis is put on marine energies, taking into account the position of Dunkerque as a port.

**Short term**

Energy savings in transport will be mainly due to the bonus/malus as defined in 2008: a penalty (“malus”) is given to high emission cars (> 160 gCO2/km in 2008) and a premium (“bonus”) to low emission vehicles (< 130 gCO2/km). This measure has been quite successful in 2008 even if it is also due to high oil prices (low CO2 emission means low consumption).

Development and modernisation of public transport (Hytane project), central management of road traffic and promotion of alternative ways of transportation will be promoted. A reduction of 5% of energy in transport is a reachable target.

**Mid term**

Hytane fuel will used in public transport on 50 buses and the first cars will be fuelled with pure hydrogen. For private cars, it is expected that electrical cars at low price with a convenient autonomy (> 300 km) will be available as well as first tests of V2G (Vehicle to Grid) systems to optimize the global energy system.

**Long term**

A major issue will be the inter-connection of heat, electricity and transport energy systems. It will give an optimization of the global system, increasing the penetration of renewable energy (RE) sources through storage of excess power and limitation of grid extension.

Systems like V2G (Vehicle to Grid for electrical and hybrid cars) and new fuels like Hythane and hydrogen from RE sources have to play a major role in this view.

**Gdansk**

**Short term**

Continuation of tram line construction.

**Mid term**

Natural gas buses in public transport – still there are some problems in operation of compressed natural gas (CNG) trucks and buses in winter conditions

**Long term**
Multifunctional cars – cars which are used for heat or electricity production (‘garage generation’) could become an important option. Only cars with fuel cells fuelled with NG, biogas, hythane or hydrogen are tailored to this purpose. Only approx. 20% of this energy is converted to heat and electricity. The rest is dedicated directly to transport.

Gothenburg

Overview
The major obstacle to reach a sustainable society would be the transport sector, as it looks today. However, during the coming decade (until 2020), technical solutions that aim for a fossil fuel free transport sector, will most likely be presented.

This would mean that from 2020 to 2050, the vehicle population will be continuously exchanged to fossil free vehicles.

If especially the mobility issues are to develop in a sustainable way, city planning is essential. This involves making room for public transport and making the city denser. If more people live in a certain area, the need for transportation decreases. Also, where work places and shopping centres are located are very important. This also affects the possibility of utilising waste heat through district heating, because of heat losses.

Mid term
Gasification of biomass is commercialised, which for Gothenburg, and the transport sector means a much larger supply of 2nd generation fuels, be it biomethane DME or whatever the market forces decide. In the RES diagram it is assumed that the dominant 2nd generation fuel is biomethane.

Valencia

Mid term and long term
For the Hydrogen Generation we hypothesized that in the beginning (2021) it will come exclusively from Natural Gas Reforming. In 2030 we introduce the Electrolysis technology process, with a 20% share in Hydrogen Generation, growing to 40% in 2040 and 60% in 2050.

Figure 1 Hydrogen Generation Module
Arnhem – De Stoere Houtman

Mid term
Electric cars will be introduced. This will lead to lower energy consumption and, when electricity is generated with renewable sources, to a real improvement in the Path-to-RES.

Lochem

Mid term
In the mobility sector more cars will drive on gas and electricity.