Why is ethanol given emphasis over methanol in Sweden?

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Abstract

Both ethanol and methanol are liquid alcohols that can be produced from non-fossil raw material and can be blended with gasoline/diesel. Methanol was preferred in the seventies and eighties but the interest for methanol ended and instead ethanol programs were initialized. Today Sweden has two commercial plants and one pilot plant on ethanol production but no plant on methanol production. The aim of this study is to get an understanding for why ethanol is given emphasis over methanol in Sweden. A technical comparison of the two alcohols is done to investigate advantages and disadvantages of the fuels. Then policy decisions taken that impacts the use of methanol or ethanol are analyzed. It is not obvious that one of the alcohols has a technical advantage over the other. One explanation for why ethanol is given emphasis over methanol in Sweden can be found in agriculture policy. The three-party energy policy agreement was made between the social democrats, the liberals and the centre party, i.e. two parties in favour of nuclear and one not wanting nuclear. The centre party traded the postponement of a decision to close down nuclear power against favourable conditions for large scale introduction of grain-ethanol. The grain-ethanol production, which today dominates the Swedish alternative fuel market, may decide the technological path for decades to come and maybe it will hinder, not just methanol but other alternative fuels to enter the market.

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1. Introduction

There are mainly two reasons to consider bio alcohol fuels, to replace gasoline or diesel for transport. Most countries wish to be less dependent on imported oil and alcohol fuels can be used in a strategy for the security of energy supply.

The second reason is reducing fossil carbon dioxide emissions. The Swedish parliament has set up an environmental goal called “Begränsad Klimatpåverkan”, which means limited climate impact. The atmospheric concentration on greenhouse gases should be stabilized on 550 ppm carbon dioxide equivalents. Today Sweden emits 7.9 ton CO_2-equivalents per capita per year and to reach the goal for year 2050 it is necessary to reduce the emissions into 4.5 ton CO_2-equivalents per capita per year (SPI, 2003).

Total deliveries of gasoline and diesel in Sweden were 5.5 million cubic meters of gasoline and 3.7 million cubic meters of diesel in year 2002. Excluding diesel for stationary machineries, 2 million cubic meters of diesel remain as transportation fuel. The transportation sector stands for 40% of total CO_2 emissions, in Sweden, and the emissions from the transportation sector has increased during the last 25 years where CO_2 emissions have decreased from most other sectors (SPI, 2003). If there are no preventive measures taken, the CO_2-emissions from the transportation sector are expected to increase by 35% until 2010 due to larger transportation needs (European Commission, 2000). Better efficiency in vehicles will probably not be enough to keep emissions stable (Schafer&Victor, 1999).

Some energy-economy system models conclude that fuel changes are more costly in the transportation sector than in other sectors, per ton of CO_2 reduced, i.e. it is more cost-effective to substitute fossil fuels for biomass in power and heat production (Azar et al, 2003). However, political decision makers today indicate that a transition away from fossil fuels in the transportation sector is very important and one European example of this is the biofuel directive introduced by the European Commission in May 8, 2003. Member States should ensure that a minimum proportion of biofuels and other renewable fuels are placed on their markets on a certain date. A reference value for these targets are 2%, calculated on the basis of energy content, of all petrol and diesel for transport purposes placed on their markets by 31 December 2005 and a reference value of 5.75% placed on their markets by 31 December 2010 (European Commission, 2003). Furthermore, an objective of 20% substitution by alternative fuels in the road transport sector by the year 2020 is stated in the report Green Paper on European strategy for the security of energy supply (European Commission, 2002).

1.1. Swedish research on alcohol fuels in the seventies and eighties

Swedish economy is highly dependent on the use of oil, particularly as fuel for transport. The first reminder of the need for safe and regular oil supply came in 1956 in the form of the Suez crisis. At that time, the Suez Canal was closed and oil tankers had to carry their cargoes all the way around the African continent. The conflict had more to do with political control of distribution than with actual supply, but the constraints became a fact. In Sweden the crisis led to a period of restrictions in the use of private cars (Zacchi&Vallander, 2001).

The oil price shocks initiated in 1973 became an even more important landmark in the history of the modern economy. Rapidly increasing oil prices lead to that energy policies were high on the agenda in most countries. Serious questions were raised about the vulnerability of industrialised countries. In response to those concerns, the OECD founded the International Energy Agency (IEA) in 1974, which initial objective was to deal with issues related to security of energy supply (Zacchi&Vallander, 2001).

In Sweden, the Energy Minister Carl Tham, in January 1979, appointed a commission, called OED[1], with the aim of studying alternatives for oil. Due to lack of alternative fuels for transport, OED suggested in 1980, a large scale introduction of methanol in Sweden. A methanol project started with a small introduction of 15% methanol blend in gasoline, M15, (Sterner et al, 1998) and a combined methanol and heat plant was planned to be built in Nynäshamn, close to Stockholm. The plan was that methanol would substitute 10% of gasoline and diesel use during the eighties (Energimagasinet, 1981).

Åke Brandberg at Svensk Metanolutveckling, (Swedish Methanol Development) writes in 1981, that "methanol has the highest energy exchange rate out of all possible synthesis and is therefore without doubt the cheapest possible transportation fuel that can be produced except fuels produced from oil". The only problem with methanol, discussed in 1981, is that blends larger than M15 requires some adjustments in engine material. Solution discussed is that this material adjustment should be made as standard already at car manufacture, where extra costs could be neglected. OED suggests that this adjustment should be made to all cars from year model 1985. All cars beyond 1985 year model should then be prepared to use blended methanol fuel up to M20 (Energimagasinet, 1981).

In November, 1989, there was an article in Scientific American about future methanol-fuelled cars including illustrations of a possible car design. Optimistic statements such as "Cool burning methanol needs no radiator so the front of the car can be very streamlined, the earth would love it" are made. Advantages such as higher efficiency and fewer emissions than a conventional gasoline-fuelled car, were also discussed (SciAm, 1989).

Between 1975 and 1985, Swedish research on alternative motor fuels is organised around a large number of projects and several approaches are tested. Different raw materials are tried, such as wood, peat and coal. Different products and conversion techniques are studied, such as liquefaction and gasification. The main line during

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[1] OED is an acronym for oljeersättningsdelegationen (Free translation - Commission of oil substituting).

this period is the development of the gasification process for producing methanol (Zacchi&Vallander, 2001).

1.2. Swedish research on alcohol fuels in the nineties

For many years methanol and not ethanol is thought as the coming alcohol fuel. Håkan Matson in the newspaper Expressen reports from the car exhibition in Los Angeles 1993. “Here you can look into the future and we see cars fuelled by hydrogen, natural gas and methanol” (Matson, 1993). Ford Taurus is one example of such a car prepared for methanol use (Carstedt, 2004).

The foundation of Swedish ethanol development (in Swedish: Stiftelsen Svensk Etanolutveckling, SSEU, from 1999, BioAlcohol Fuel Foundation, BAFF) drives, in 1994, through a project of starting an ethanol plant in Örnsköldsvik with cellulose from sulphite pulp as raw material (Geijer, 1994).

In 1998 Agroetanol gets permission to erect an ethanol plant in Norrköping, with the purpose of producing ethanol fuel for 5% blend in gasoline. Agroetanol, together with the gasoline companies, plan to gain experience and create conditions for further expansion (BAFF, 2004).

During the nineties research efforts on alternative fuels are concentrated to ethanol. The Swedish ethanol programme was established in 1993 and was granted an increased level of governmental funding. The general trend in Swedish research funding over the past decade is to establish programmes instead of giving support to individual projects. The programme form gives a more comprehensive view of the field of interest, and makes it easier to choose specific issues on which to focus, to the exclusion of others. Ethanol has remained the main option for a Swedish renewable liquid motor fuel since then (Zacchi&Vallander, 2001).

1.3. Current Swedish production and use of alcohol fuels

At Domsjö in Örnsköldsvik, for SEKAB, 24,000 cubic metres (24 million litres) of ethanol is manufactured from sulphite pulp. Agroetanol has a plant, in Norrköping, which produces 50,000 cubic metres (50 million litres) of ethanol from wheat. There is a research and pilot facility established at Domsjö factory in Örnsköldsvik producing ethanol from cellulosic biomass. Furthermore, more than 10,000 cubic metres of surplus wine ethanol from Europe was imported in 2003 (SPI, 2003, Hansson et al, 2004). Today Sweden has two commercial plants and one pilot plant on ethanol production but no plant on methanol production.

The ethanol, produced by Agroetanol, is bought and distributed by all major gasoline companies in Sweden. The mixing, 5% ethanol into gasoline from this plant, occurs at the oil depots in Norrköping, Stockholm and Södertälje. In this area all unleaded 95 octane gasoline contains ethanol, E05.

E05 may occur within today's distribution system and can be used by all cars since no modification of vehicles are needed. Ethanol is also used as E85 in Flexible Fuel Vehicle (FFV). The number of FFV cars have increased from 250 cars in January 2001 into 6562 cars in September 2003 (Miljöfordon, 2004) of which 6125 are Ford Focus Flexifuel, 375 are Ford Taurus and 62 are Chevrolet PickUp. The number of FFV-cars is projected to increase with approximately 5000 cars per year (Finansdepartementet, 2003). E100 is primarily used in ethanol trucks and buses. Stockholm has the largest fleet of ethanol buses, 250 buses. No Swedish vehicle is fuelled with methanol or methanol blends.

1.4. Governmental R&D support on alcohol fuels

Research on alternative motor fuels has received continuous governmental funding since 1975. Unlike the situation in other countries, Swedish governmental support in this area has not been adjusted to the fluctuations in oil price (Zacchi&Vallander, 2001).

Between 1975 and 1985 governmental support was given to a large number of projects, mainly for the development of the gasification technique. The centre of these activities was the Royal Institute of Technology in Stockholm. A large part of these research activities were eventually moved to Studsvik, where gasification research has been conducted since then, by the research company TPS Termiska Processer AB. However, governmental support for methanol research was withdrawn in 1985. This decision was based on the conclusion that the production of bio-methanol could not compete economically with methanol produced from natural gas (Zacchi&Vallander, 2001).

A memorandum from the Swedish government in June 2003 presents the current support for research and development regarding production of alternative fuels for transport, see Table 1. The aim of the support is to reduce costs for the production of alternative fuels that have a potential to reduce fossil fuel emissions (Memorandum, 2003).

Table 1: Current support for research and development regarding production of alternative fuels.

Program	Type of fuel	Support period	Governmental support
Ethanol production from wood	Ethanol	1998-2004 (7yr)	210 MSEK (30 MSEK/yr)
Alternative transportation fuels	Primarily possible fuels from the syn-gas (H2 and CO) produced by gasification of wood, i.e. Methanol, FT-diesel*, DME** and hydrogen.	2002-2006 (4yr)	56 MSEK (14 MSEK/yr)

*) Fischer-Tropsch Diesel

**)Di-Methyle-Ether (CH3-O-CH3)

Current governmental support for the ethanol production program, is 30 million SEK (appr. 4 million USD[2]) per year and current governmental support for methanol (among other fuels) is 14 million SEK (appr. 1.8 million USD) per year. The supported period is also in favour for ethanol, 7 years, compared to methanol, 4 years.

1.5. Ethanol subsidises

In December 19, 2002, the government decided to strike off the energy tax from the ethanol part in E85 (85% ethanol in gasoline) which decreased the E85 price by 0.94 SEK/litre (SPI, 2003). Between January and April 2003, the gasoline prices fluctuated between 9.20-10.33 SEK/litre (mean value 9.76 SEK/litre). The price of a litre ethanol (gasoline equivalent) was 9.62-9.75 (mean value 9.69 SEK/litre gasoline equivalent). The ethanol price[3], on fuel stations, then became lower than the gasoline price (SPI, 2003).

Furthermore, company cars that are leased have reduced benefit tax if it is an ethanol car. Most municipalities also subsidize cityparkings, or ethanol cars may park free of charge, and ethanol cars will maybe be excluded from a coming congestion charge in Stockholm.

It is very likely that methanol cars, if there were any, would have received the same benefits, but since there are no methanol cars on the market, ethanol cars and infrastructure take a great share of the alternative fuelled vehicle market.

1.6. Summary Swedish research and use of alcohol fuels

Swedish research on alternative liquid fuels can be divided in two phases. In the first period during the seventies and eighties Swedish research is organised around a large number of projects focused on the development of the gasification process for producing methanol from wood, peat and coal. Swedish energy policy was in favour of methanol and OED suggested in 1980, a large scale introduction of methanol in Sweden.

In the second period during the nineties until today Swedish research is organised around large programmes focused on ethanol production. Today there are two commercial plants and one pilot plant on ethanol production. No plant on methanol production. Sweden has approximately 7000 cars and 400 buses running on ethanol. No vehicles run on methanol and today ethanol receives a larger governmental R&D support than methanol.

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[2] One SEK is 0.13 USD (2004-04-29)

[3] Ethanol price gasoline equivalent (30% more ethanol is needed to drive the same distance as gasoline)

2. Comparison of methanol and ethanol

Methanol (CH_3OH) and Ethanol (C_2H_5OH) are quite similar products. Both are liquid homogeneous alcohols with a simple chemical structure and can be used as motor fuels. They can be used as neat fuels or blended with gasoline (or diesel) as direct additives or in the form of ethers (MTBE methyl tertiary butyl ether and ETBE ethyl tertiary butyl ether). Both alcohols have a high octane rating (higher than gasoline) and are therefore most suitable for Otto-engines. When using ethanol or methanol in Diesel-engines, some chemical ignition improver has to be added to the fuel or more likely an external ignition source, such as a glow plug, can be foreseen to the engine. Both alcohols emit lower quantities of carbon monoxide, nitrogen oxides and particulate matter compared to diesel (Ahlvik&Brandberg, 2001). Since both alcohols contain hydrogen they are also possible to supply hydrogen for fuel cell applications. Some drawbacks of methanol are that it is more corrosive and can therefore damage the engines that are in service today. It is also more toxic and has a lower energy content than ethanol (Zacchi&Vallander, 2001).

2.1. Production technology

Production of liquid bio-fuel can be divided into two main processes. One is thermo-chemical and the other is bio-chemical (Ahlvik&Brandberg, 2001). Gasification of wood chips with high pressurized oxygen, or air, is an example of a thermo-chemical process and fermentation is an example of a bio-chemical process.

2.1.1. Bio-chemical process – fermentation

The bio-chemical process transforms starch, cellulose or sugar from biomass into a sugar solution, which then is fermented into ethanol.

The production of ethanol from sugar and starch are well-established technologies, which have been used for many years, mainly for the production of alcoholic beverages, but also for ethanol fuel in the past few decades. Ethanol for transportation fuel purposes are today produced around the world from sugar cane, corn, wheat and other sugar or starch rich biomass. These processes result in an animal feed by-product. The total economy of the process depends on the market for the by-product (Zacchi&Vallander, 2001).

Processes for the production of ethanol from lignocellulosic materials are much more complex and not yet fully developed. The main by-product of the process is a solid residue consisting mainly of lignin, which can be used as a fuel for heat and power production. The bio-chemical process that are in commercial use in Sweden today produces ethanol from wheat and the manufacturing process is illustrated in Figure 2.

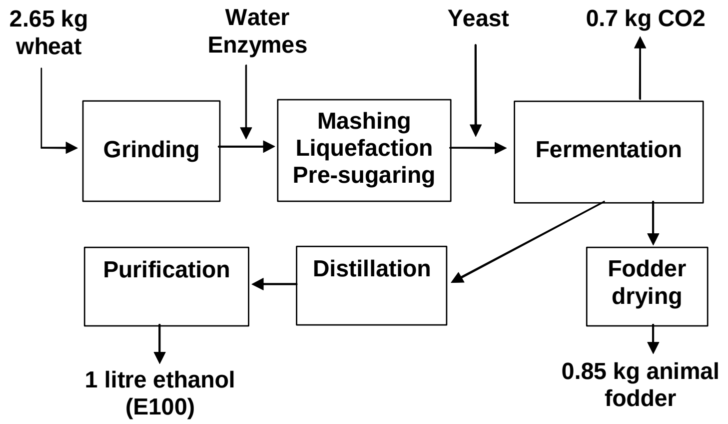

Fig. 2: Scheme of the Swedish bio-chemical process from wheat into ethanol at Agro-ethanol plant in Norrköping (Agroetanol, 2004).

The following steps, presented in Figure 2, of a fermentation process are:

1) Grinding: Wheat comes to the plant by truck, which unloads in an inlet funnel. With conveyors, the wheat is transported further to cleaning and temporary storing. Milling is done in a hammer mill, where the whole grain is ground to flour.
2) Starch conversion: The flour is mixed with water to a slurry after which enzymes are added. The starch in the grain (approximately 60% of the content) is then converted to a sugar solution, called mash.
3) Fermentation: Ordinary bakery yeast is added to the sugar solution and the sugar is converted to ethanol and carbon dioxide.
4) Distillation and purification: In order to separate the ethanol from the mash a distillation is carried out and finally a complete removal of water is made in a molecular sieve after which water-free ethanol is obtained.
5) Fodder drying: The alcohol free mash, called stillage, goes to drying. The stillage, which is rich in protein and thereby a high-value animal feed, is dried with steam. The dried product is finally pelletized.

At the plant in Norrköping, wheat is used as the main feed stock. Approximately 135 000 tonnes of wheat is needed for producing 50 million litres of ethanol. In mid-Sweden this means that 25,000 hectare[4] are needed (Agroetanol, 2004).

2.1.2. Thermo-chemical process – gasification

Usually gasification of biomass is carried out in fixed or fluidized bed reactors with air as gasification agent. The gasification produces a synthesis gas which mainly consists of carbon monoxide and hydrogen. Out of this energy rich gas a range of transportation fuels can be produced, such as di-methyl ether (DME), Fischer-Tropsch diesel, hydrogen or methanol. The gasification process, in a fluidized bed reactor with air as gasification agent, is illustrated in Figure 1.

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[4] Approximately 62,000 acres

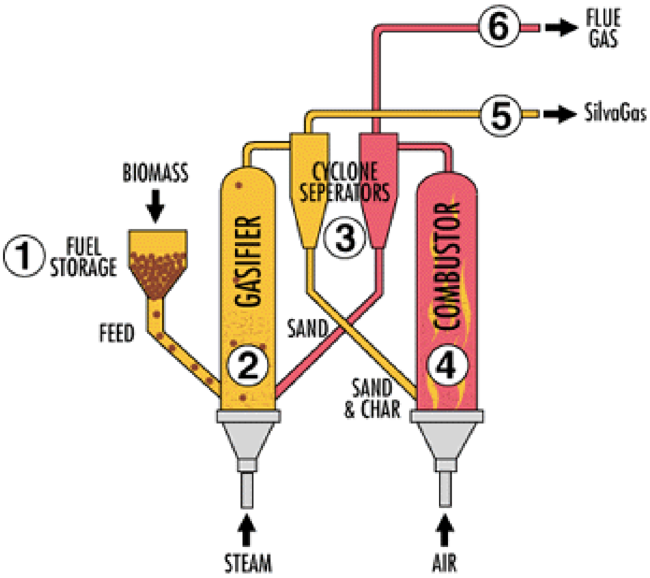

Fig. 1: Scheme of a biomass gasification processes with a fluidized bed system. High pressurized air (or oxygen) are blown on sand which will be heated and added to the gasifier where the fuel is turned into the energy-rich synthesis gas, in figure called SilvaGas (FERCO, 2004).

The following steps, presented in Figure 1, of a gasification process are:

1) Wood chips or other biomass materials are loaded into the fuel hopper. The wood handling system removes metal impurities and oversized pieces or particles and discharges the fuel into the gasifier.
2) In the gasifier the biomass is mixed with hot sand (~1000º C), turning it into a synthesis gas and residual char. Steam enhances the mixing.
3) The residual char and cooled sand are separated from the syn-gas by a cyclone separator and discharged to the combustor. Flue gas from combustion is then not mixed with the syn-gas.
4) The sand is reheated in the combustor by adding air (or oxygen) and burning the residual char. The reheated sand is removed from the combustion air by a cyclone separator and returned to the gasifier.
5) The syn-gas is cleaned in a scrubber and can be used for a variety of applications e.g. synthesized into methanol.
6) The flue gas is a valuable source of heat that can be recovered for uses such as biomass drying or steam production (FERCO, 2004).

Dry wood chips are preferable used as fuel, but a dryer can be installed to allow wetter fuels to be used. The circulating bed material (sand) acts as a heat carrier from the combustion to the gasification zone. When sufficiently cleaned, the synthesis gas can be used for applications such as:

- Powering higher-efficiency (~40%) conversion devices such as gas turbines
- Retrofitting existing oil or natural gas fired equipment to operate on biomass
- Providing fuel for fuel cells or other distributed generation technologies
- Synthesizing liquid fuels, or chemicals such as methanol (Energytech, 2004, Stevens, 2001).

2.2. Energy conversion efficiencies in alcohol production

The net energy balance in producing the fuels is an important factor when comparing the two alcohol fuels. Conversion efficiencies in alcohol fuel plants, are summarized in Table 2. The energy balances in biomass production have not been taken into account.

Table 2: Conversion efficiencies in fuel productions.

Source:	Methanol from cellulosic biomass		Ethanol from cellulosic biomass		Ethanol from sugar		Ethanol from starch	
		incl. by-prod.		incl. by-prod.		incl. by-prod.		incl. by-prod.
Larson, 1993	0.55[a],0.63[b]		0.30[c],0.64[d]		0.35[e]		0.37[f]	
Goldemberg&Moreira,1999					0.36[g]			
Ahlvik&Brandberg, 2001	0.54[h]	0.65[i]	0.48[j]					
Wright&Feinberg, 1993	0.47							
Swedish Nat. Energy Adm., 1999			0.36-0.42[k]	0.50-0.60				
Gielen et al, 2003	0.56		0.33		0.56[l]		0.56[l]	
Haroon S Kheshgi et al, 2000							0.30[m]	
Leister B Lave et al, 2001				0.75[n]			0.25[p]	
Lee R Lynd								

a,b) The conversion efficiency is defined as higher heating value of methanol divided by the higher heating value of all energy inputs to the process assuming that all external energy requirements are provided using the same type of fuel as the feedstock. a) Based on using an oxygen-blown, pressurized, bubbling fluidized-bed gasifier under development by the Institute of Gas Technology in the USA. b) Based on using a twin circulating fluidized-bed gasifier being developed by the Battelle-Columbus Laboratory in the USA.

c) Overall efficiency by acid hydrolyses.

d) Projected total energy conversion efficiency to ethanol with improved xylose (5-carbon sugar) fermentation.

e) Typical yield of hydrous alcohol in Brazil is 77 litres per ton of cane processed. Energy content (HHV) in sugar cane, is 17 MJ/kg DM (Wirsenius, 2003), energy content (HHV) in ethanol is 23.4 MJ/litre (BIN, 2004) and dry matter for sugar cane is 0.30 (Wirsenius, 2003).

f) Net fraction of input corn energy converted to ethanol.

g) Yield per ton of sugarcane is 79.5 litre ethanol. (Converted using the same data as in comment e)

h, i) Lower heating value in optimised, self-sustained plant using oxygen steam gasification. If by-products such as hot water for district heating the conversion efficiency is raised to 0.65

j) The theoretical yield will be 435 litres/tonne dry substance assuming fermentation of both C5- and C6-sugars. LHV-basis

k) Theoretical conversions from 1 ton of softwood are 644 kg hexoses, 68 kg pentoses, 280 kg lignin and 80 kg other. The energy content in softwood is 5.2 MWh and the theoretical quantity of ethanol (712kg or 454 litres) has energy content 2.7 MWh, which indicate a theoretical energy conversion efficiency of 52%. In a real process, the yield obtained is less than the theoretical value due to losses in the conversion and due to the needs for heat and power in the process. An ethanol yield of 70-80% of the theoretical value is assumed to be feasible in future plants.

l) Aggregated conversion efficiency for sugar and starch.

m) 0.37 litres ethanol per kg dry corn (12-15% moisture)* 0.798 kg/litre.

n) Net energy balance producing ethanol from lignocellulosic feedstock including co-generation of electricity.

p) Net energy balance producing ethanol from corn.

The conversion efficiencies differ from study to study, highly dependent on assumptions on useful by-products or not, but generally it can be said that methanol productions has higher conversion efficiencies than ethanol productions.

2.3. Well-to-wheel efficiency

Depending on what engine is used in a vehicle, a well-to-wheel energy efficiency, also called system efficiency, can be useful to compare. In Table 3, system efficiency is presented relative an Otto-engine fuelled by gasoline.

Table 3: Well-to-wheel system efficiencies for alcohols used in three different engines, related to a gasoline fuelled Otto-engine (=100) (Ahlvik&Brandberg, 2001).

Feedstock	**Engine**	**Methanol** Relative system efficiency	**Ethanol** Relative system efficiency
Biomass	Fuel cell	81.6	67.6
Biomass	Otto	67.0	57.0
Biomass	Diesel	72.7	63.1

Highest system efficiency is found for methanol used in a fuel cell engine. The only combination, which gives ethanol higher system efficiency compared to methanol, is if ethanol is used in a fuel cell and methanol in an Otto-engine.

2.4. Production cost

Brazil, which is the largest ethanol producing country, has the lowest ethanol production cost, very close to the cost of producing gasoline from oil. In Brazil ethanol is produced from sugar canes, which is the most cost efficient way of producing ethanol. Sugar canes can not grow in Swedish climate instead ethanol has to be produced from starch or lingo-cellulose, which needs a pre treatment to release the sugar before the fermentation can take place. The need of a pre treatment, hydrolyses, increases the production cost.

Since methanol from biomass and ethanol from cellulose not are in commercial production today, estimates on production costs have been done by engineers and presented in Table 4.

Table 4: Estimated production cost in SEK/litre. Including distribution but excluding taxes (Ahlvik&Brandberg, 2002). The Brazilian data comes from Goldemberg&Moreira,1999

	Estimated Year	Prod. cost SEK/litre	Gasoline equivalent (incl. distribution) SEK/litre	Comment
Gasoline	2000	2.00	2.85	Mean cost 2000
Ethanol, sugar	2000	2.00	2.85	Brazilian production
Ethanol, grain	2000	6.00	10.00	Actual cost, 2002
Ethanol, cellulose	2010 2020	4.60 3.80	7.90 6.70	Engineer estimate Engineer estimate
Methanol, bio gasification	2010 2020	2.50 2.00	6.20 5.20	Engineer estimate Engineer estimate

Best estimated cost for ethanol produced from cellulose is higher than estimated cost for bio-methanol. Estimated costs, in Table 4, do not take the by-product heat into consideration. If surplus heat can be used, for example in district heating, production costs can be decreased.

2.5. Advantages and disadvantages of methanol and ethanol

The energy content in both alcohols is lower than in gasoline. One litre of gasoline corresponds to 1.7 litres of ethanol and 2.2 litres of methanol. A blend of 5% of ethanol has so far shown no increase in fuel consumption, probably due to its high octane rating. Using E85 increases the fuel consumption by 30% (SPI, 2003).

2.5.1. Methanol properties

Methanol, which has the molecular formula CH_3OH, is also called methyl alcohol, wood alcohol or wood spirit. Methanol is a colourless liquid, boiling at 64.9° C, solidifying at –93.9° C and burns with a non-luminous flame. It is a violent poison; many cases of blindness or death have been caused by drinking mixtures containing it. Pure methanol is an important material in chemical synthesis. Its derivatives are used in great quantities for building up a vast number of compounds, among them many important synthetic dyestuffs, resins, drugs, and perfumes. It is also used in automotive antifreezes, in rocket fuels, and as a general solvent (Encyclopedia Britannica, 2004).

2.5.2. Ethanol properties

Ethanol, which has the molecular formula C_2H_5OH, is also called ethyl alcohol, grain alcohol, or just alcohol. Pure ethanol is a colourless, flammable liquid with a boiling point at 78.5° C. Ethanol is toxic, affecting the central nervous system. Moderate amounts relax the muscles, but larger amounts producing coma and death. Industry use of ethanol is for example antifreeze, disinfection solvent and engine fuel (Encyclopedia Britannica, 2004).

2.5.3. Methanol and ethanol distribution and storage

Ethanol can use the same infrastructure as oil-products but since methanol is corrosive it is somewhat more difficult to store and distribute.

Deep-sea distribution of methanol increased dramatically in the 1980’s and 1990’s. As a result, dedicated methanol tankers became common. Every month about 550,000 metric tons of methanol is distributed between sellers and buyers across the United States. Typical inland distributions involve tanker trucks, railcars or barges. Methanol can be stored in mild steel tanks, which are commonly used throughout the United States (DeWitt&Co, 2002).

Import of methanol to Sweden is in the future considered to be accomplished by large tankers over oceans to terminals as for crude oil or oil products. The energy usage for the ship operation is calculated to be 1.2% of transported energy as methanol. For distribution from terminal to fuel stations with road tankers, the fuel consumption (incl. 0.2% evaporation loss) is presumed to be 1% (Ahlvik&Brandberg, 2001).

Domestically produced methanol from biomass is presumed to be distributed with road tanker or a combination of coastal ship and road tanker consuming motor fuel corresponding to 2% of the energy in transported methanol (Ahlvik&Brandberg, 2001).

Domestically produced ethanol can be distributed with a motor fuel consumption corresponding to 1.5% of the energy in transported ethanol. This is somewhat lower than in the case of methanol distribution (Ahlvik&Brandberg, 2001).

2.6. Summary comparison methanol and ethanol

It is not obvious that one of the alcohols is to prefer over the other. Fermentation from grain is a well known technology and commercial plants operate today where we still don’t know if the biomass gasification technology will work on a large scale. Methanol is toxic and has a higher energy loss during distribution but has higher technical advantages, i.e. system and conversion efficiencies, compared to ethanol.

3. Policies, which impact alcohol fuel production

Since mid seventies different governments, have tried to draw up guidelines for energy policy, but always in dissonance between parties, especially regarding nuclear policy.

3.1. The three-party energy policy agreement in 1991

In Sweden there was a referendum in March 1980 about an expansion of nuclear power or not. The outcome became that an expansion should be allowed but as soon as the supply of electricity could be ensured, without jeopardizing Swedish welfare, the nuclear plants should be phased out. In March 1980 no final year was decided but in June the same year, it was decided that the last nuclear reactor should be closed down at year 2010 (Moberg, 1988).

In spring 1988, the year 2010 was discussed again in the context of expected nuclear reactor life time. The consideration report from the committee of commercial policy (in Swedish: Näringsutskottet), NU40:1987/88 on page 41 and 53, stated again that the year 2010 was the final year and also that the first nuclear reactor should be taken out of operation in 1995 and a second reactor in 1996. It was also specified that the two reactors should be one in Barsebäck and one in Ringhals (NU40:1990/91, p3 and p42-43).

In autumn 1990 preliminary negotiations started between representatives of the social democrats, the liberal party and the centre party, with the aim of drawing up sustainable guidelines for energy policy. The negotiations led to an agreement, between the three parties, in January 15, 1991 (NU40:1990/91, p40). This agreement was stated in the government bill called 1990/91:88 and was later accepted by the parliament and substituted the earlier energy policy from 1988.

In this three-party energy policy agreement, the year 2010 still remain as final year, for nuclear phase out, but now it is more of a recommendation. The nuclear phase out are said to depend on that power supplies from renewable sources have become large and cheap enough to make sure that the nuclear phase out not will impact Swedish industry and welfare. For the same reasons, the year 1995 and 1996 were erased from the earlier energy policy decided in 1988 (NU40:1990/91, p3, p43 and p46).

Historically the centre party has been the party most against nuclear power. To be able to draw up sustainable guidelines for energy policy and bridge the dissonance, it was important to invite the centre party into the negotiations. The centre party has a tradition of being an advocate of Swedish farmers and it is natural that they negotiate to favour their interest. In the three-party energy policy agreement there are a lot of financial support for energy efficiencies, different renewable energy projects but most of all support for ethanol production, see Table 5. To give a simplified picture, the centre party traded the postponement of a decision to close down nuclear power plants against favourable conditions for large scale introduction of ethanol.

Table 5: Governmental support decided in the three-party energy policy agreement in 1991 (NU40:1990/91, p3-4).

Program	Support period	Governmental support
Energy efficiency and energy efficient technology	5yr	150 MSEK (30 MSEK/yr)
Support to the National Board for Consumer Policies to produce energy declarations	1yr	5 MSEK
Biomass (excl. peat) fuelled heat and power plants: 4000 SEK/kW installed effect for plants ordered after Feb 20, 1991 1500 SEK/kW to restore plants built July 1990-Feb 1991 1000 SEK/kW to restore plants built 1985-June 1990	5 yr	Approx 1000 MSEK (200 MSEK/yr)
Small wind power plants	5 yr	250 MSEK (50 MSEK/yr)
Solar panels	5 yr	50 MSEK (10 MSEK/yr)
Ethanol production	No stated time limit	356 MSEK/yr

Note that no supports for any methanol projects, or other products from bio-gasification, are given.

The large ethanol support is said to be financed from the economic compensation farmers already get to put fields in fallow, more detailed presented in the chapter “Agriculture policy 1990”.

3.2. Agriculture policy 1990

In spring 1990 the Swedish parliament agreed to a new agriculture policy. The governmental bill was called 1989/90:146 and resulted in a large scale deregulation of arable land. To adjust agriculture to the open market, and reduce the grain surplus, farmers were financial compensated if they put fields in fallow. This changeover support was in the three-party energy policy agreement in 1991 discussed to finance ethanol production projects. The field in fallow could be used to grow wheat for energy purpose and instead of supporting the farmers, the financial support could be used to build an ethanol production plant (NU40:1990/91, p119).

An ethanol plant was built by Agroetanol on Händelö, an island less than 10 km from the centre of Norrköping, and owners are the Federation of Swedish Farmers, LRF, by 91% and Swedish Farmers' Supply & Crop Marketing Association, SLR by 9% (BAFF, 2004). The plant fulfilled the requirements stated in the three-party energy policy agreement and received governmental financial support (NU40:1990/91, p120)

3.3. Landscape policy

Energy plantations, e.g. Willow and the harvest (wood chips) could suit as raw material for either methanol via bio-gasification or ethanol produced by the fermentation of lingo-cellulosic biomass. Both technologies more cost-efficient compared to the production of grain-ethanol. Energy plantations grow however to about 4-5 metres height, where wheat fields are much lower.

In September 1988 the Swedish Energy Agency and the Swedish Environmental Protection Agency got the governmental commission to investigate how a Swedish environmental energy system could be designed. Results were presented in a report 1989. In the report energy plantations were discussed but also how the plantation should be done to avoid negative changes in the landscape. In the report it says that in a hilly or rough terrain, for example fields close to a forest, it is unsuitable with energy plantations due to the landscape picture. In large open landscape with many fields close together it can be a positive effect with some fields of energy plantations as a change (Hansson, 1989).

In a memorandum, from The Ministry for the Environment and The Ministry for Economics, it is stated that Sweden has 2.7 million hectare agriculture land of which 1.7 million hectare are used for grain production receiving financial support due to agriculture policy (SweStat, 2002). Due to this agriculture policy at least 10% of the arable land receiving financial support must lie fallow, i.e. 170,000 hectare, but fields may be used to grow industry and energy plants.

Today the real area which lie fallow are 270,000 hectare and Sweden has today 15,000 hectare of energy plantations and the ethanol plant in Norrköping demands wheat grown on 25,000 hectare. In Sweden today it is possible to use additional 230,000 hectare for energy plantations (Memorandum, 2002).

The Federation of Swedish Farmers, LRF, is an interest and business organisation for those who own or work farm and forest land, and for their jointly owned companies in the Swedish agricultural co-operative movement. LRF has about 150,000 members and its mission is to create the conditions for sustainable and competitive companies and to preserve the open Swedish landscape (LRF, 2004)

Sweden has 230,000 hectare of field fallow which could be used for energy plantations, but by doing so it would conflict Swedish policy to preserve the open landscape.

3.4. Swedish policy on path-dependency

Path-dependency means that established technologies have an advantage over newcomers, not because they are better, but because they are widely used. When oil will be substituted for alternative fuels the first alternative that dominates will most likely improve its production costs and advantages, and thus lock out its competitors. Fuel alternatives will be reduced and a dominant design is created. Historically it can be seen that it does not have to be the technology that has the largest development potential that is selected and locked in (Sandén&Azar, 2004).

When introducing new technologies, it is important to observe that there is a risk of going in the wrong direction. If a path for some reason turns out to be a dead end, valuable time may be lost. The choices made today may decide the technological path for decades to come (Sandén&Azar, 2004).

In Sweden there is a broad common agreement over political parties to avoid lock-in technologies. The following quotations show that politicians are aware of the phenomenon. “The introduction of alternative fuels should be technology neutral and not favour a certain technology” (TU03:2002/03). In a parliament debate May 27, 2002, three persons have opinions about path-dependency and the importance of not lock into a specific technology. The former Minister of Industry, Björn Rosengren, says “We can today not predict the future environmental alternative transportation fuel which will have the best economy in future. That is why the Swedish government first of all provides research and development on different fuels”, The Minister of Finance, Bo Ringholm, says “A rapid technology development is going on and it is important to not lock into a specific alternative, since there are quite a few” and Ingegerd Saarinen from the Green Party says “We can today see a situation where strong actors receive all benefits but week actors, and future actors not yet on the market, receive no benefits at all (Debate May 27, 2002).

Two more statements can be sorted in under the path-dependency awareness. Gudrun Schyman from the Left Party says “To stimulate innovations on this area it is important that the legislation assume that the state cannot predict future energy technologies” (SK776:2000/01), and a combined document from Vinnova, The National Road Administration and The National Environment Protection Board, states that “The short term fuel development must not complicate or hinder a coming hydrogen introduction” (Vinnova and others, 2003)

3.5. Swedish policy on cost-efficiency

In Sweden there is a broad common agreement over political parties to choose a cost-efficient alternative fuel. Again some quotations, found in political documentations, show that politicians are aware of the phenomenon. In the governmental budget bill in 2002 a tax strategy for alternative fuels was presented. “The taxes should be designed to promote the environmental goals in a cost-efficient way” (Memorandum, 2003). The Minister of Finance, Bo Ringholm, has declared the importance of cost-efficient solutions. “Energy and carbon taxes are meant to, in a cost-efficient way, increase the environmental good and economical efficient solutions of alternative fuels” Jonas Ringqvist from the Green Party says “Green certificate should be developed in that way as it can be used for the introduction of alternative fuels. They can in a cost-efficient way be important for renewable transportation fuels” (Ringqvist, 2001). The former Minister of Industry, Björn Rosengren, says “It is important considering an expansion of biofuels that these are cost-efficient solutions to current transportation fuels” (Rosengren, 2002) and finally Ingegerd Saarinen from the Green Party says ”The National Road Administration has pointed out that hydrogen and new synthesized fuels such as methanol and DME are the most interesting alternatives to gasoline and diesel. They are assumed to be more cost-efficient than ethanol” (Saarinen, 2002).

4. Discussion and conclusions

By going through the material on methanol and ethanol, a picture of alcohol fuel history from the seventies until today, has appeared. It looks like methanol was preferred in the seventies and the eighties and in Sweden it came that far that M15 was sold on fuel stations. The interest for methanol then ended and instead ethanol programs were initialized. Zacchi and Vallander states that the methanol period ended due to that the biomass gasification process could not compete economically with methanol produced from natural gas, but I believe that this is just a part answer. In my point of view it has to do with changes in the purpose of alternative fuels for transport. During the seventies and eighties the main goal was to be less dependent on imported oil. Methanol, from coal or natural gas, was the most cost-efficient alternatives and gasification of biomass was interesting in order to use domestic primary energy. In the late eighties climate protection became a more important reason for alternative fuels for transport and using fossil primary energies were not an option any longer. This in combination of a steady and quite low oil price, at that time, probably led to less interest in gasification technology and ended the interest for methanol.

4.1. Answers found in the comparison

By comparing advantages and disadvantages, it is not obvious that one of the alcohols is to prefer over the other. Methanol seems to be in favour comparing the system and conversion efficiencies and is also assumed to have a lower production cost compared to ethanol. It is also a fuel that fits well both in Otto engines and in fuel cells, but methanol has some disadvantages i.e. (i) that it is toxic, (ii) that it corrodes on most metals and (iii) that producing methanol from biomass is a new technology and not yet proven in large scale.

4.1.1. The argument “methanol is toxic”

The first disadvantage of methanol is that it is toxic. This argument has, however, not hindered it to be used earlier in history. M15 has been used in Swedish cars so methanol has obviously been delivered to fuel stations in the seventies. Today methanol is a common fuel in sports cars e.g. drag-racing, and people in that business have learned how to handle the fuel. Large quantities of methanol are regularly distributed across the world in both sea tankers on trucks or in railcars. It seems that methanol is handled pretty much in the same way as gasoline. The fact that it is toxic doesn’t seem to be a strong argument for not using it as a transportation fuel.

4.1.2. The argument “methanol corrodes”

Methanol corrodes on most metals, which is a disadvantage for methanol if it is used in an Otto engine but it will not corrode fuel cells suited for methanol. Materials in Otto engines, in infrastructure and other material in touch with methanol can be adjusted to avoid corrosion. The extra production cost, for adjusting car engines, will likely be quite small if methanol prepared cars can be produced at large scale. Since methanol currently is used in sports cars, it shows that it is possible to use high concentrations of methanol in Otto engines. The fact that methanol corrodes on most metals doesn’t seem to be a strong argument for not using it as a transportation fuel.

4.1.3. The argument “bio-gasification is a new technology”

The third disadvantage for methanol is that gasification of biomass is a new technology and not yet proven in large scale. Fermentation from grain is a well known technology, where for example Sweden has been producing alcohol beverage for at least hundred years. How to produce methanol from fossil fuels are well known but if the fuel must be CO_2-neutral, i.e. produced from biomass, the technology is not well known. This is a strong argument if a rapid introduction is wanted. It will then not be time to wait for technologies not yet proven in large scale.

4.2. Answers found in Swedish policy

In 1990, Sweden had a grain surplus and to reduce the grain surplus farmers were financial compensated if they put field in fallow. One year later the three-party energy policy agreement was made between two parties in favour of nuclear and the Center Party not wanting nuclear. It is most likely that in this horse trading agreement, the Center Party agreed to keep on to nuclear power on some conditions, i.e. some benefits for Swedish farmers, who are their main voters. The large scale ethanol program solved at least two problems. First, fields in fallow could be used again and a new usage of wheat was found. Second, fields in fallow have a tendency to go back into forests and by growing wheat, the open landscape could be sustained. Furthermore, the Center Party received heaps of “political points”, which is important to keep and recruit voters.

Ever since the three-party energy policy agreement, ethanol receives a larger governmental R&D support than methanol (or any fuels from bio-gasification).

4.3. The future of bioalcohols

It is most likely that the demand for alternative fuels will increase in Europe and Sweden as an effect of the European Commission biofuel directive. Highest potential to fulfil the directive are fuels currently on the market, e.g. biogas, biodiesel (RME) and grain-ethanol. Ethanol has entered the market with quite small technical difficulties but methanol, in the form of MTBE, which has been tried on the US market, has experienced problems. In the 1990’s, MTBE production capacity grew in the United States from about 4,000 barrels per day to more than 250,000 barrels per day but it is now expected that US demand will be reduced due to concerns of groundwater contamination from leaking underground storage tanks (DeWitt&Co, 2002). The future of ethanol looks brighter than the future of methanol.

If the European Commission biofuel directive doesn’t succeed, i.e. that biofuels not will be forced into the transportation sector, there are reasons to believe that biofuels might not play a major role in the transportation sector even if stringent carbon emission policies are adopted. Biomass can be expected to be more cost-efficiently used for heat and electricity generation than if converted into transportation fuel (Azar et al., 2003). The reason for this is that the potential supply of biomass is limited (Berndes et al., 2003) and that the conversion efficiency of biomass into liquid fuels is low compared to using biomass for heat. The prospects for biofuels may improve if residual heat and by-products can be efficiently used.

It is not obvious that one alcohol is to prefer over the other and it is neither obvious that an alcohol are the preferable alternative fuel. This paper compares ethanol and methanol, but most important is to keep the doors open for a variety of alternatives. Sandén and Azar state that it is probably premature to let a created market select among alternative fuels. Rather, variation or “technodiversity” should be promoted. Research efforts, should continue on a number of technologies for alternative fuels production and use, e.g., ethanol from woody biomass, thermo-chemical gasification of woody biomass for the production of methanol, DME and Fisher Tropsch liquids (Sandén&Azar, 2004).

By going through the energy policy process in this matter, and identify what have influenced policy decisions, I found that the three-party energy policy agreement in 1991 have had the most impact on why ethanol is given emphasis over methanol in Sweden. I have found some examples where politicians are aware of the importance of avoiding decisions leading to lock-in technologies, but when decisions actually are made it is not always that neutral. Horse trading in politics does not always consider these aspects. The decisions made on grain-ethanol production may decide the technological path for decades to come and by establishing this fuel on the market it could lead to a lock-in technology situation, meaning that other technologies, e.g. hydrogen or fuels from bio-gasification, may have difficulties entering the market.

I would like to finalize this paper by using a quotation from Sandén and Azar, which very much conclude my own opinion: “The key issue in bringing new technologies possible to commercialize, is learning. We therefore propose this decade to be the decade of great technological experiments and failures. We present a let-a-hundred-flowers-bloom strategy for the next couple of decades.” (Sandén&Azar, 2004).

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