# Memorandum: Methanol factory in Hagfors

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**VärmlandsMetanol AB/Miljöcentrum ©**

**Summary**
Atmospheric emissions of greenhouse gases, mainly carbon dioxide from fossil fuels, are one of the great environmental menaces of our time. Motorism in Sweden accounts for roughly 40 per cent of the country's fossil-based carbon dioxide emissions, i.e. approximately 20 million tons annually. These emissions can be eliminated by changing to biomass-based motor fuels such as methanol/wood alcohol, i.e. methyl alcohol ($CH_3OH$).

Methanol production by gasification of biomass offers twice the energy yield of ethanol produced by conventional fermentation of cereals. There is in Sweden sufficient forest acreage available for methanol to be produced on a large scale, whereas ethanol made from agricultural produce can only be a marginal motor fuel, owing to the limited availability of agricultural land.

Methanol made by large-scale gasification of wood has a production cost of about SEK 6 per gasoline equivalent litre. The corresponding cost of ethanol produced by fermentation of Swedish agricultural produce is of the order of SEK 10. Ethanol produced by fermenting sugar made from decomposed wood cellulose has a production price of about SEK 14. And yet no methanol factories based on biomass have been built in Sweden.

VärmlandsMetanol AB was formed in 2001 for the construction in Hagfors of a pilot plant producing methanol, district heat and possibly electricity from forest biomass, using gasification technology. VärmlandsMetanol AB is a public company registered with the Nordic Securities Depository.

The initial purpose was to demonstrate in Hagfors the possibilities of gasification technology and to create a research and development centre for large-scale methanol production. The Miljöcentrum Foundation has invested, non-commercially, some MSEK 5 in the project, the funding for which has also included MSEK 0.5 from Sparbanksstiftelsen Alfa and a number of small grants from the EU and other sources.

A study has been made of a 21 MWth pilot plant planned to produce 19,000 tons of methanol annually as well as district heat and, possibly, electricity. An environmental impact study and a risk study have also been completed. The investment cost is estimated at some MSEK 600, giving a production cost of about SEK 13 per gasoline equivalent litre. Thus the pilot plant cannot be financed on a comercial basis.

Initially, therefore, it was presumed that some MSEK 100 would be obtainable from the Swedish Energy Agency, in which case a corresponding amount could automatically be forthcoming from the EU. Government part-funding, however,

has proved unobtainable, due partly to one-sided commitments to ethanol and to the Energy Agency's established practice. Pure research projects can obtain 100 per cent funding, whereas pilot and/or demonstration plants are given much more niggardly treatment. Gasification technology as such is a proven technology, which has long been in use for producing methanol from coal, and so no research is needed before wood can be substituted for coal as raw material.

In view of the difficulties of obtaining government part-funding, Värmlands-Metanol has decided to build a full-scale plant of the order of 100 MWth, which will mean a production of 116,000 million litres per year at a cost of about SEK 6 per gasoline equivalent litre. The plant will further supply heat for the local district heat network with a peak value requirement of 15 MW. This will involve an investment of some MSEK 2,000 to be funded through the market, i.e. via stock markets and banks.

VärmlandsMetanol AB is owned by the Miljöcentrum Foundation, the Municipality of Hagfors, LRF (the Federation of Swedish Farmers) and 726 private persons and 37 small corporations – these last mentioned through a recently completed new stock issue.

The driving force of the project is Miljöcentrum, which has been engaged in gasification technology R&D for about 30 years now through biophysicist Arthur Tampling, Ph.D., formerly of the Rand Corporation and Livermore Lawrence Radiation Laboratories, California.

The County Forestry Board takes a very favourable view of the project because it can create a sales opening for forest biomass, of the inland region has plenty.

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**Methanol – questions and answers**

**1 What is methanol?**

The chemical formula for methanol (methyl alcohol), popularly known in Sweden as "wood spirit" (i.e. wood alcohol), is $CH_3OH$. The name "wood spirit" is due to methanol previously having been produced by dry distillation of wood. Methanol is an important basic raw material in chemical industry.

Methanol is a high-octane motor fuel regularly used in speedway motorcycles and in certain racing car events. It is an obligatory motor fuel at Indianapolis, for example, the reason being that, unlike gasoline, it can be extinguished with ordinary water. As a motor fuel, methanol can be used on its own or mixed with gasoline.

Like ethanol, and in contrast to gasoline and diesel, methanol degrades rapidly in soil, surface water and groundwater, in the event of escapes into the environment.

## 2 Production

As mentioned above, methanol used to be produced by dry distillation of wood. That process is based on heating wood with limited air supply, whereupon tar, methanol and various combustible gases are formed. The yield is miserable.

Methanol is an important basic raw material in chemical industry. Industrial methanol production is based on natural gas, which is converted to methanol by means of shifting, a chemical process in the presence of certain catalysts.

Methanol made from natural gas increases atmospheric carbon dioxide content when burned, owing to its fossil origin. Methanol made from wood, on the other hand, is part of the ecocycle, due to its biological origin, and consequently does not result in any net growth of atmospheric carbon dioxide content. In other words, methanol made from wood is a suitable motor fuel for helping to reduce fossil carbon dioxide emissions.

As has already been mentioned, the production of methanol by conventional dry distillation of wood has a very poor yield. By gasifying wood, however – a more sophisticated form of dry distillation – some 95 per cent of the wood's energy content can be converted into producer gas – a mixture of hydrogen, methane gas and carbon monoxide. This gas can then be converted into methanol, using the shifting technique already mentioned. Gasification combined with shifting results in about 60 per cent of the wood's energy content being obtained as methanol and 40 per cent as heat. The methanol can be used as motor fuel, the heat for industrial processes or in a district heating network.

Gasification technology is the most efficient means of producing electricity and district heat simultaneously. Using gasification technique, electricity production in relation to a given heat base can be doubled compared with conventional Combined Heat and Power Technology (CHP). The gas is burned first in a gas turbine powering an electricity generator. The exhaust fumes from the turbine are hot enough to produce steam to drive a steam turbine, which also powers a generator. The residual heat is sold as district or industrial heat.

Municipalities with extensive district heat production have considerable possibilities of building in electricity production by converting the district heating plants to gasification CHPs. Production of this kind should of course be based on biofuel, given the problems of carbon dioxide. From an economic viewpoint the gasification process can be optimised in combined facilities producing electricity and district heat in winter and methanol in summer.

Gasification technique, with coal as the energy raw material, is a well-tried technology. In Germany during the Second World War, large quantities of producer gas were produced from coal. The gas was shifted to methanol, which was used by the Wehrmacht as a motor fuel.

In Sweden during the war years, thousands of cars were fuelled with producer gas made from firewood/charcoal. The gas was produced in generators fitted to the cars; basically, a generator was a large container in which the fuel was converted to gas by burning it with a heavily throttled air supply.

**3 Motor fuel properties of methanol**
Environmentally, methanol is clearly superior to ethanol, gasoline and diesel, i.e. when burned it produces cleaner fumes than they do. In addition, methanol has a high octane rating.

Methanol and ethanol are more aggressive than gasoline to certain components in vehicle fuel systems. Vehicles with injection engines, however, can take a low admixture of methanol or ethanol in gasoline – at least 20 per cent – without any technical problems occurring.

**4 Experience of methanol admixture**
In Sweden during the 1940s it was common practice for petrol to be eked out with methanol obtained as a by-product of certain forest industry processes.

In the 80s the Nynäs Company sold petrol with a 15 per cent admixture of methanol (M 15). Plans existed at that time for introducing this kind of fuel on a large scale, based on coal gasification in Nynäshamn.

Cars ran excellently on M 15, but environmentally this fuel was unsuitable, since the raw material for producing it was coal. For this reason, sales of M 15 were discontinued after a few years.

In the 1980s methanol was introduced in California in the form of M15 (a blend of 15 per cent methanol and 85 per cent petrol) and M85 (a blend of 85 per cent methanol and 15 per cent petrol) to reduce emissions. From the mid-1980s to the late 1990s some 16,000 methanol FFVs were sold in California. Hertz Rental Cars had a fleet of 2,000 methanol FFVs in Los Angeles and Sacramento. Methanol pumps were available all over the state. Methanol pumps were also installed in 15 other US states.

The petroleum industry responded with cleaner-burning petrol, so-called reformed petrol. The environmental argument in favour of using methanol as a transportation fuel was thereby weakened and methanol faded away.

However, the methanol project demonstrated that there were no technical barriers to making methanol-fuelled cars or installing storage tanks and pumps. It also showed that methanol could be stored and distributed safely and economically.

At the height of the US methanol programme there were four methanol FFVs on the market: Ford Taurus, Chrysler Dodge Spirit, Chrysler Concorde and GMs Lumina. Today's ethanol FFVs are actually based on the FFV technology developed for methanol.

Under Miljöcentrum and VärmlandsMetanol auspices in 2006, a 12-year-old Volvo 854-512 GLE was driven for over 10,000 km, with neither technical modifications nor problems, using 96-octane gasoline with various admixtures of methanol. To date the car has been driven for 640 km with a 10 per cent methanol admixture, 2,760 km with 15 per cent, 1,500 km with 20 per cent, 1,290 km with 25 per cent and about 13,000 km with 30 and 35 per cent respectively. Fuel

consumption, irrespective of methanol content, was about 0.9 litre per 10 km up to and including the 30 per cent admixture, after which it increased slightly.

**5 How will methanol from the Hagfors plant be used?**
The current upgrading of the feasibility study for the pilot plant indicates that the plant will have a capacity of 100 MWth. The corresponds to about 100,000 tones of pure methanol annually, to be added to low-octane commercial gasoline (initially 10 per cent). Cars running on this kind of mixture will work in the same way as if fuelled with ordinary gasoline. Fuel consumption will remain unaltered, despite the methanol having lower energy content than gasoline, owing to the high-octane rate and vaporisation value of the methanol. Present-day distribution systems can handle a mixture of this kind without any alterations being needed to filling station tanks and pumps. Today many new stations can manage both E85 and M85.

**6 Sale**
Contracts concerning admixture and marketing will be concluded with one of the larger oil companies in Sweden. Discussions on this subject are now in progress.

**7 Why Hagfors?**
The Hagfors area has a surplus of forest biomass and scope for selling residual heat within a planned extension of the local district heating network. Further to this point, see below.

Hagfors has both an industrial tradition and engineering works, which, if the project turns out well, can supply components or perhaps even turnkey facilities for production of methanol, heat and electricity.

**8 The energy balance**
When methanol is produced by gasifying biomass, about 60 per cent of the energy in the biomass is transferred to the methanol produced. The efficiency level, then, is 60 per cent. The rest of the energy turns into heat, which can be used in district heating networks or industrial processes. Methanol production, then, can be the hub of combined energy production facilities with a very high level of efficiency. The gas obtained in the first stage of the process can also be used for electricity production, i.e. for powering gas turbines, in combination, for example, with district heating.

**9 The environmental effects**
Gasification of wood is an enclosed process, unlike conventional wood-fuelled boilers. In principle, no sulphur, nitrous oxides or particles are released into the atmosphere. The wood ash contains important minerals, which should be returned to the forest or farmland soil as pellets.

**10 The employment effect**
About 50 persons will be employed at the Hagfors facility. Production of energy raw material, transport. Services etc. will also result in 40 or more job opportunities.

**11 Raw material**
Wood biomass from the neighbourhood will be the energy raw material used at Hagfors. The supply of wood within the Municipality of Hagfors will suffice for a 200 MWth plant. Distribution channels for wood exist in Hagfors already, this being the fuel used in an existing district heating plant. The County Forestry Board takes a very favourable view of the project because it can create a sales opening for wood.

**12 Why methanol?**
Methanol production based on gasification of biomass offers a higher energy yield than any other method of producing liquid biomass-based motor fuel. The energy efficiency is twice that of ethanol production based on conventional fermentation.

Forest growth in Sweden since the 1940s has exceeded felling by about 25-30 per cent, which means that some 6 million hectares of forestland are idle. Current forest growth therefore provides scope for methanol production, which, without encroaching on the needs of forest industry, would cover about 30 per cent of Sweden's motor fuel demand.

It would only take 3 million hectares of energy forest, however, to cover Sweden's entire demand for motor fuel with methanol made by gasifying energy forest. The requisite acreage for this kind of methanol production exists in the form of some 2.3 million hectares of pasture and arable land taken out of production and reafforested since the 1920s, plus about 300,000 hectares of set-aside arable land and various marginal lands.

From the National Forest Survey terrain classification, it can be deduced that there are now some 3 million hectares of forest land with soil conditions, gradient, ground conditions etc., which are suitable for energy forest cultivation. In other words, there is scope for 3 million hectares of energy forest, which will not encroach on the timber requirements of conventional forestry industry – not that it would be a bad thing if forest industry did have to compete for timber. In the long term, moreover, rising oil prices can make it more profitable, both commercially and for the national economy, to upgrade timber to methanol rather than to pulp, paper and sawmilling products.

**13 Fuel cells**
The cars of tomorrow will have electric motors powered by fuel cells. Methanol is unquestionably the best liquid fuel option for fuel cell propulsion, a context in which ethanol is practically worthless.

**14 Why not ethanol from agricultural produce or wood?**
Ethanol (ordinary alcohol) can be equated with methanol in terms of environmental effects and functioning in ordinary combustion engines.

Production of ethanol from agricultural produce is a good deal more expensive. Besides, the acreage necessary for such large-scale production is not available, because it would take six times Sweden's present agricultural acreage to meet the country's demand for motor fuel based on ethanol from agricultural produce. In

addition, energy corresponding to about 6 million hectares would be needed for sowing, spraying, manuring, harvesting etc. Cereal-based ethanol, therefore, can never be more than a marginal motor fuel, even if totally exempted from fuel tax. At EU level, cereal-based ethanol can at most replace roughly 5 per cent of fossil motor fuels.

Ethanol can also be manufactured from wood (by the CASH method), in which case the cellulose is decomposed to sugars, which are fermented in the conventional way. This method was originally developed in the Soviet Union in the 1920s. Experimentation with the CASH method has been in progress for some years now in Örnsköldsvik.

The production cost of this kind of ethanol, however, is roughly twice that of producing methanol from wood using gasification technology, added to which, methanol production with gasification technology, based on wood, gives twice the energy return of ethanol production by the CASH method. The latter, accordingly – compared with methanol production – requires twice the amount of wood input per "energy amount" of motor fuel.

**Investment in a national biomass-based motor fuel should therefore concentrate on methanol made from wood using gasification technology and not, as hitherto, on ethanol produced by fermentation of agricultural produce and/or by the CASH method.**

## 15 Price

Methanol manufactured by large-scale gasification of wood has a production cost of about SEK 6 per gasoline equivalent litre. The corresponding production cost of ethanol made by fermenting Swedish agricultural produce is of the order of SEK 10, and SEK 14 by the CASH method. It was already established by a Swedish Government Commission in 1996 that methanol, given production facilities on a com-mercially reasonable scale, was the cheapest of the biofuels studied (methanol, ethanol and biogas), in relation to both quantity and energy unit (SOU 1996:184). It should be noted that the methanol production cost stated above refers to dedicated methanol production without any revenues from the sale of residual heat for district heating systems.

## 16 "Rival" gasification projects

A pilot plant for gasification of black liquor was commissioned in 2006 in **Piteå**. That facility has a thermal rating of 3 MW, as compared with the 100 MW rating of the facility planned in Hagfors.

The purpose of the Piteå plant is to recover process chemicals from the pulp industry while at the same time producing synthetic gas for production of electricity/heat and/or alternatively methanol, the aim being to demonstrate that the gasification process is robust and dependable and accordingly capable of replacing the soda digesters which are used in the pulp industry and, from an energy viewpoint, are pretty inefficient. The project is receiving about MSEK 65 funding for two years from MISTRA and other interests. Theoretically about 25-30 per cent of Sweden's motor fuel demand could be covered if all Swedish soda digesters were replaced with gasification plants of the above mentioned type. Large-

scale black liquor gasification, however, cannot come into question before most of today's soda digesters have been pensioned off, i.e. in 10 or 20 years time.

About ten years ago, Sydkraft erected a pilot plant (thermal rating 20 MW) in **Värnamo** for producing electricity by gasifying biomass. The experiment turned out well from a purely technical point of view, but Sydkraft mothballed the plant after a few years' experimental operation, owing to the inability of gasification technology at that time to compete with "low" energy prices.

The plant has been taken over by a holding company owned by the Municipality of Växjö and Värnamo Energibolag but due to be transferred to Växjö University. The aim was to study the gasification process over the next few years in order to devise a gas rich in hydrogen. The project was planned to continue for five years, up to and including 2009, at a cost of some MSEK 200. The Swedish Energy Agency (STEM) and the EU are funding it. However, STEM in December 2007 decided not to release any further funding for the Värnamo plant. The reason is that it has not been possible to get industry to invest money into the project. This was one of the requirements when STEM in made a decision to conditionally continue supporting the plant.

The said project notwithstanding, there is an obvious need for the plant now being planned in Hagfors. This plant differs essentially from the Piteå facility, in that its feedstock will be biomass, not black liquor.

The Värnamo project in turn is to be regarded as a purely experimental project aimed at optimising the gasification process. The Hagfors plant, on the other hand, is a first step towards commercial production, a step aimed at demonstrating the entire chain from input timber of the addition of methanol to motor fuel and the return of residual products from the process to forest land.

**17 What can government do?**

Sweden's one-sided commitment to ethanol should be reviewed. The E85 ventures are suboptimal, unnecessarily pre-empting huge sums of money for E85 pumps and presupposing tax-subsidised E85 cars. The cheapest way of using the limited quantities of ethanol, which exist and will be available, is by low admixture to all gasolines.

Within the EU, Sweden should move for production of biomass-based motor fuels to be based on each Member State's raw material circumstances.

**Summing up,** facts indicate that large-scale, sustainable native production of biomass-based motor fuel ought primarily to focus on methanol produced by gasification of wood. If all petrol and diesel fuel in Sweden is to be replaced by "biomethanol" of this kind, wood alcohol factory investments will be needed totalling some MSEK 100,000. This would create some 10,000 permanent jobs, reduce national emissions of fossil carbon dioxide by about 20 million tons annually and improve Sweden's trade balance by several billion kronor.