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Environmental and economic assessment of biomethanol for the biodiesel production

Short study

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LIST OF ABBREVIATIONS USED

eq.	equivalent
bio-SNG	bio-synthetic natural gas
MeOH	methanol
RME	Rapeseed oil methyl ester
GHG	greenhouse gas
RES-D	EU Directive 2009/28/EC
Biokraft-NachV	Directive on Requirements for the sustainable production of Biofuels
TEG	triethylen glycol
SRC	Short rotation coppice
FR	Forest residues
EEG	Renewable Energy Act

1 BACKGROUND AND OBJECTIVE

The environmental assessment of biofuel production and use is becoming increasingly relevant as a result of the current political conditions at the European and national level. As a result of the intense public debate about the sustainability of an increased biofuel use, the European Commission introduced sustainability criteria for biofuels by the means of the EU Directive 2009/28/EC (RES-D). With the enactment of this directive and its implementation within Germany under the terms of the Biofuel Sustainability Ordinance (Biokraft-NachV), compliance with specific savings targets for greenhouse gas emissions will become obligatory for biofuels [1], [2]. For this reason it will be of vital importance for biofuel producer to be able to identify and make use of possible environmental optimisation potentials in the greenhouse gas balance of their fuel. Amongst other options, the replacement of fossil energy sources, the use of methanol from biogenic raw materials as well as the environmental optimisation of the conventional methanol production could provide a possibility for improving the GHG Balance of biodiesel produced from rapeseed oil. In order to evaluate the approach of using methanol from biogenic raw materials for the biodiesel production in greater detail, this brief study will compare different possibilities of the biomethanol production and use according to environmental and economic criteria. The resulting impact from the use of this biomethanol on greenhouse gas emissions and the cost of the biodiesel production will be estimated. For this purpose the first section of the study will briefly outline the basic aspects of methanol production together with a brief characterisation of the analysed biomethanol concepts. After that the defined biomethanol concepts are subjected to an environmental and economic assessment. Finally, conclusions are reached regarding the use of biomethanol in biodiesel production.

2 BASIC ASPECTS OF METHANOL PRODUCTION

2.1 Methanol production from natural gas and from biomethane

In Germany, the production of methanol is based mostly on the use of natural gas and residue oils from the production of mineral oil [3]. The processes used in industrial methanol production can be divided into the main stages shown in Fig. 1.

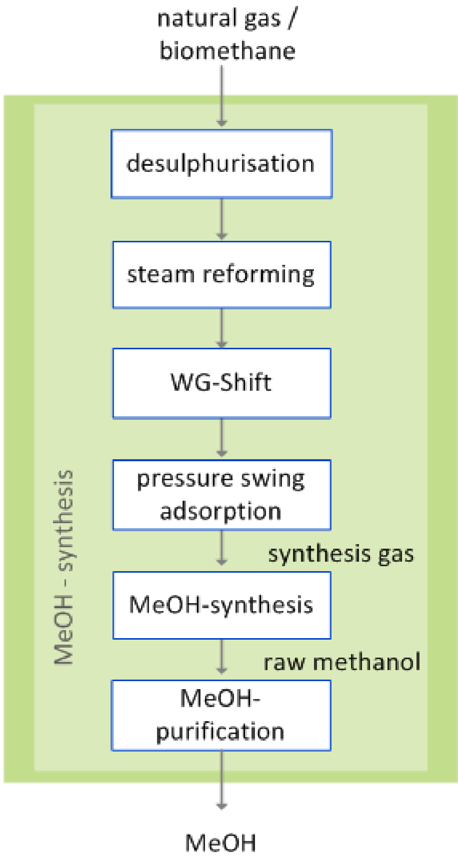

Fig. 1 *simplified process flow for methanol production based on natural gas and biomethane*

Given that a supply of (bio) methane is available (usually via the natural gas grid) to the methanol plant, the first process stage is a desulphurisation. This is followed by catalytic steam cracking (reforming) of the base product (methane). During this stage methane is first converted into hydrogen and carbon monoxide by means of steam (please see Equation 1). In an exothermic water – gas – shift reaction, which takes place at the same time, carbon monoxide and water are converted into carbon dioxide and hydrogen (please see Equation 2). By means of pressure swing adsorption the stoichiometric factor of the synthetic gas (ratio of H_2/CO) is adjusted. Depending on the synthesis conditions (which include reactor temperature, pressure and catalyst) this process usually aims at a $(H_2\text{-}CO_2):(CO+CO_2)$ ratio of 2.1:1. The synthetic gas produced in this way is purified, compressed and converted to methanol by means of catalysts (please see Equation 3). The methanol synthesis is an exothermic process. The balance of the reaction is transferred to the side of the product by means of deep temperatures and high pressures.

$$CH_4 + H_2O \longleftrightarrow CO + 3H_2 \qquad \Delta_R H^\circ = 260\ kJ/mol$$ *Equation 1*

$$CO + H_2O \longleftrightarrow CO_2 + H_2 \qquad \Delta_R H^\circ = -41\ kJ/mol$$ *Equation 2*

$$5H_2 + CO + CO_2 \longleftrightarrow 2CH_3OH + H_2O \qquad \Delta_R H^\circ = -140\ kJ/mol$$ *Equation 3*

The produced raw methanol is purified in a multi-stage distillation process which removes high volatility and low volatility by-products.

2.2 Methanol production from biosynthetic natural gas

The production of biomethanol based on so called biosynthetic natural gas (Bio-SNG) (e.g. from solid wood type raw materials) starts after the thermo-chemical conversion of the biomass by a process of gasification, multi-stage gas purification and conditioning, for the most part using the same process structure as production on the basis of natural gas. After the adjustment of the desired synthetic gas composition, the methanol synthesis and the subsequent treatment of the raw methanol are implemented similarly to the formation mechanism which is described above.

2.3 Characteristics of the analysed concepts for methanol production

As part of this short study, the production of methanol on the basis of three different raw materials was analysed. Firstly, methanol production on the basis of natural gas was analysed as the reference concept. The production of methanol on the basis of biomethane was then compared to this reference concept. The provision of biomethane was investigated on the basis of Bio-SNG from logging residues and biomethane production from biogas (two concepts with varying substrate compositions).

2.3.1 Methanol production on the basis of natural gas

The materials and energy flows required for the assessment of the methanol production from natural gas are based on a publication by Althaus et al. [4]. This publication is the basis for a corresponding data record in the Ecoinvent 2.0 database. For the purposes of this study, this data record was adapted to the conditions of methanol production in Germany. In this process, regional specific data of the original record was replaced by German regional data (e.g. electricity mix). The data record used contains all the input and output flows for methanol production from natural gas in an aggregate form. The data record also contains information about the exploration and distribution of natural gas which originates for the most part from Russian production with a small proportion coming from northern Europe.

2.3.2 Methanol production on the basis of biomethane from biogas

In addition to the reference production pathway, methanol generation from biomethane on the basis of biogas was also analysed in the course of this short study. The result of an economic and environmental evaluation of different biogas pathways can vary significantly depending on a range of influencing factors (e.g. the substrate used, the process technology used for the methanation of biogas, etc.). Therefore, two different concepts for the production of biomethane from biogas will be investigated within this study. These concepts represent the current state of technology for the biogas production in Germany. The basic aspects of these concepts are shown in Fig. 2 and Fig. 3 [5]. The investigated concepts for the biomethane production based on biogas are divided roughly into the processes biogas production and methanation. The production process covers the preliminary treatment (including ensilage, storage and substrate treatment), the fermentation (digestion with follow-up post-digestion), gas storage, the provision of heat for the fermenter by a condensing boiler and the treatment of the digestate. The methanation process includes the processes of biogas drying, desulphurisation, methane enrichment and pressure adjustment.

The substrate input for both production concepts consists of varying quantities of liquid manure, energy crops and residues. The liquid manure consists of bovine slurry, while the energy crops used are composed of a standard mixture of maize silage, whole plant silage and grain.

Both concepts reflect the current status of biomethane production and produce 250 m3N biomethane per hour. The concepts differ in the type of substrate used and in the process of methane enrichment. For example, in the first concept, as can be seen in Fig. 2, a 50-50 proportion of liquid manure and energy crops (a substrate mix consisting of maize, grain and grain crop silage) is used. In this concept the methanation process is implemented by pressure swing adsorption, a process which has so far been employed the most frequently in Germany.

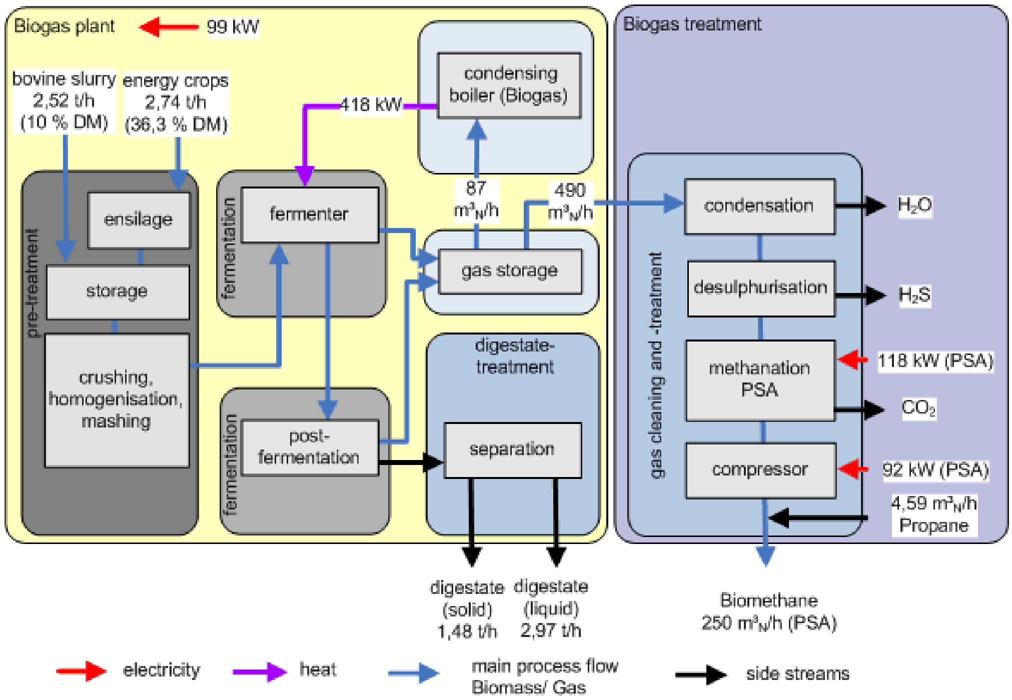

Fig. 2 first concept for methane generation from biogas for the production of methanol [5]

As a second concept for the production of biomethane the study looked at a typical biogas facility (using energy crops) that has frequently been established in recent years (cf. Fig. 3). The facility is supplied to a level of 90% with energy crops (mix from maize silage, grain and grain crop silage) and 10% bovine slurry. Since the 2004 amendment to the Renewable Energy Act (EEG) this scenario has been especially typical for newly-established biogas facilities. Because the modified composition of the substrate makes the feed-in process more complex, this concept has higher specific electricity requirements in relation to the substrate input quantity than the first concept which was looked at for the production of biomethane from biogas. On the other hand, however, the greater energy density of the used energy crops reduces the requirement for thermal energy for preheating the substrate. The substrate has to be preheated to ensure that the sensitive fermenting conditions are not disrupted (~37 °C). For this concept, a pressurised water washing is applied as the methane enrichment process instead of pressure swing adsorption. This technology has been used in Europe for many years now and is applied in particular in major new facilities.

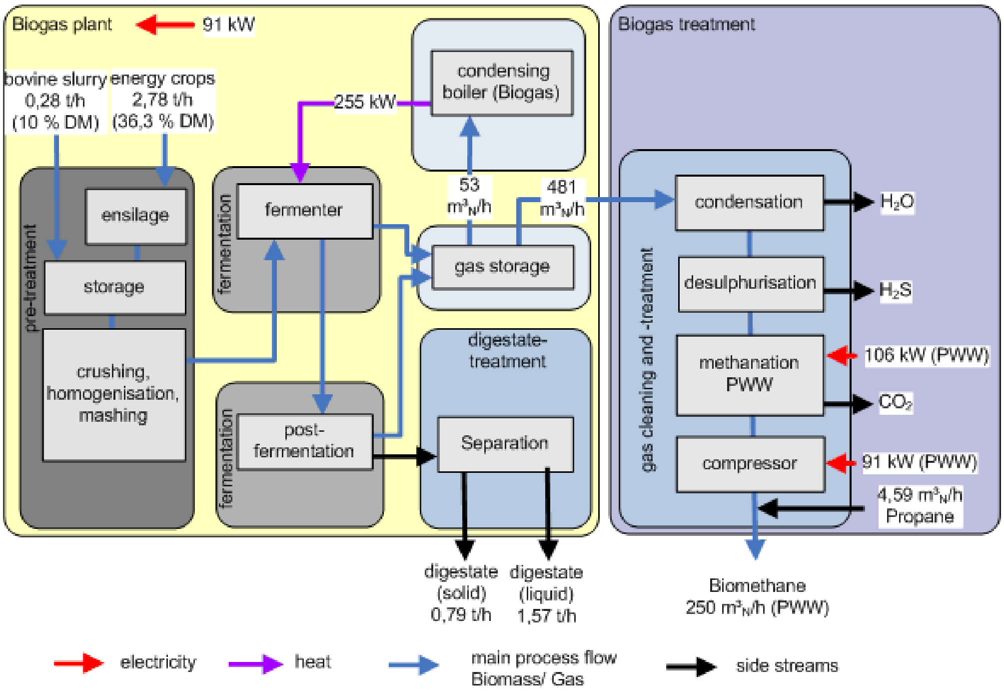

Fig. 3 *Biogas concept based on energy crops/liquid manure-2.5 MW*

The biomethane which is produced in this way and purified to natural gas quality is fed into the gas network and used for the generation of methanol by a similar process to the production of methanol from natural gas. The economic and ecological assessment of the material flows in the accounting process has also been implemented on the basis of Althaus et al. [4].

2.3.3 Methanol production on the basis of biomethane from bio-SNG

In addition to the reference pathway for the generation of methane from natural gas and the concept which has been described for methanol production on the basis of biomethane from biogas, this study also looked at methanol generation from biomethane on the basis of synthetic natural gas from logging residues (bio-SNG) as a possible option for the future. The evaluation of this option is based on a bio-SNG concept described in the publication "Natural gas substitutes from biomass for mobile application in the future energy system" [5]. With regard to its basic technical components this concept corresponds to the demonstration process for the thermo-chemical generation of biomethane set up in Güssing (Austria). Because this concept produces comparatively large quantities of biomethane, the biomethane fed in to the natural gas grid is implemented at a network pressure of 16 bar because of the. The basic characteristics and process flows of the bio-SNG concept are shown in Fig. 4.

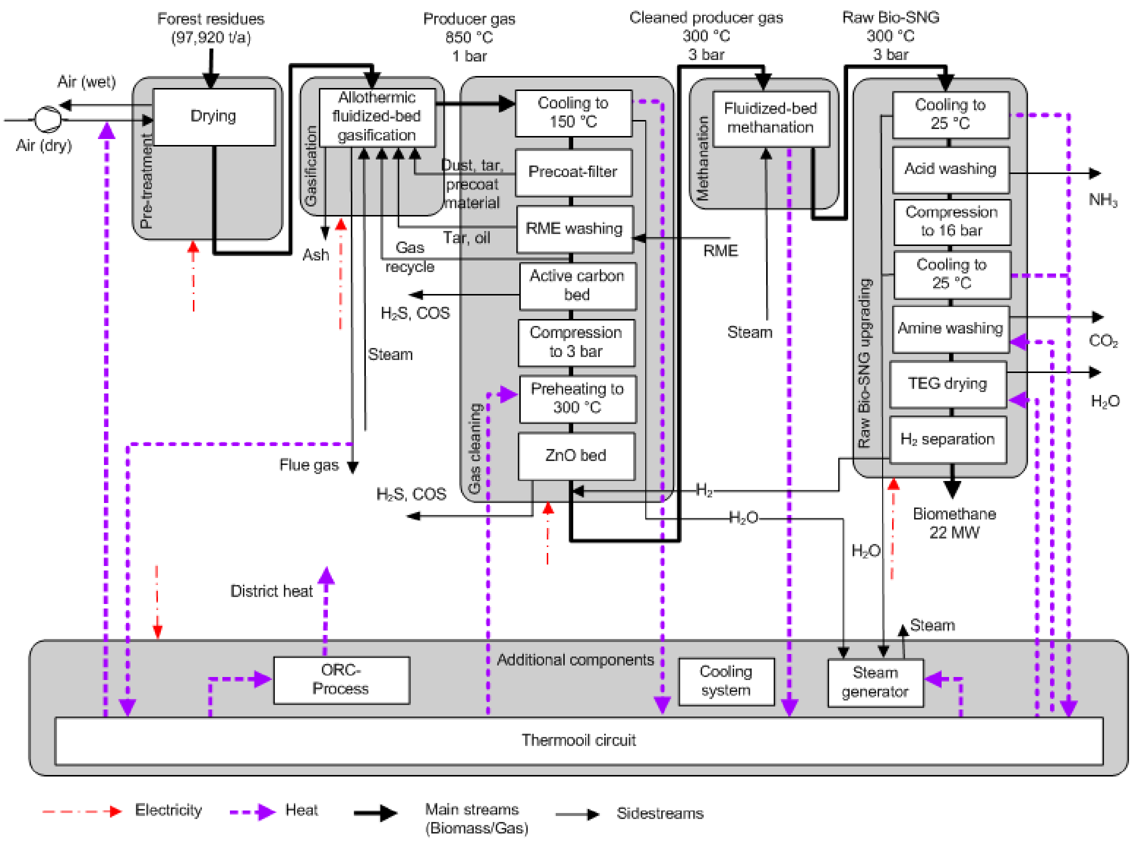

Fig. 4 concept for bio-SNG generation for the production of methanol [5]

The characteristics of the bio-SNG process are the allothermic two-bed fluidised bed gasification, the desulphurisation of the product gas by means of an activated carbon and ZnO bed and fluidised bed methanation. In addition to the methane formation, the CO shift reaction in which carbon dioxide is formed takes place in the fluidised bed reactor, which means that the carbon dioxide has to be separated out after the methanation. This is implemented by means of amine gas treatment. During the methanation process any unconverted hydrogen is removed from the raw biomethane by a membrane. In order to reduce the water content of the biomethane to a minimum (which is necessary in relation to the future application) the gas is, in addition to condensation drying, dried with triethylen glycol (TEG) [5].

The biomethane which is produced is fed into the gas network and used for the generation of methanol by the process shown in Fig. 1. The economic and environmental assessment of this process was based on material and energy flows published in Althaus et al. [4].

2.3.3.1 Methanol production on the basis of synthetic gas from logging residues and short rotation coppice

In addition to the concepts which have already been describe above, the generation of methanol from synthetic gas will be described in the next part of this short study. The modelling and calculations for this analysis are based on materials and energy flows taken from a publication by Jungbluth et al. [6]. This publication is also the basis for a corresponding data record in the Ecoinvent 2.0 database. Similarly to the data record for methanol generated from natural gas, the data record has been adapted to regional German specifications (e.g. electricity mix).

In this process, the wood gasification is based on the process flow diagram shown in Fig. 5 for the generation of methanol from synthetic gas. As described in section 2.2, the synthetic gas production is followed by methanol generation along the same lines as methanol production from natural gas.

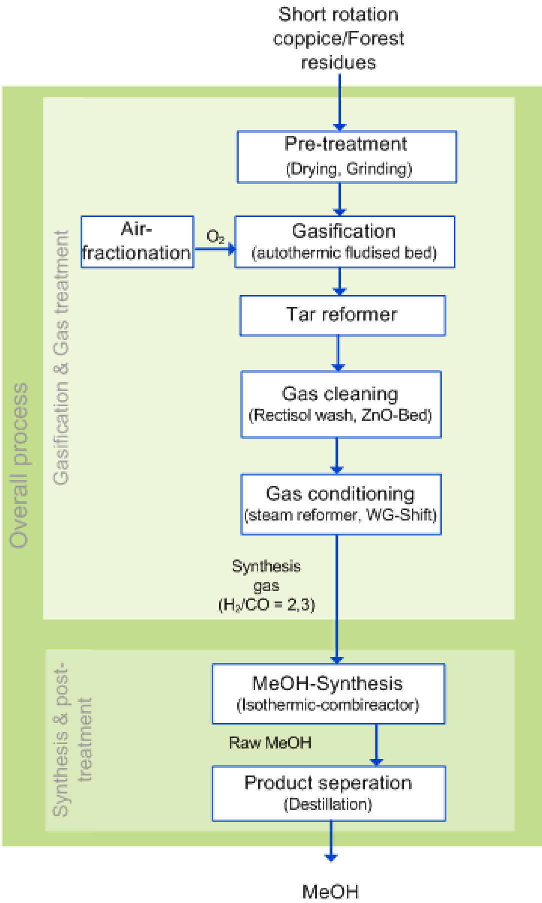

Fig. 5 concept for generating methanol on the basis of synthetic gas

3 ENVIRONMENTAL EVALUATION OF BIOMETHANOL PRODUCTION

3.1 Methodology

For the investigated methanol concepts, the specific GHG emissions per kilo of methanol were calculated. This calculation was implemented on the basis of the method of calculation defined in RES-D [1]. The selection of this methodology for determining the GHG emissions of the investigated methanol concepts results from the further analyses of the environmental benefits of using biomethanol in the production of biodiesel. In order to calculate a possible improvement in the GHG account of biodiesel by the use of biomethanol it is first necessary to determine the GHG emissions connected with the use of the varying methanol concepts on the basis of the same methodology.

The RES-D method of calculation is based mainly on the classical Life Cycle Assessment methodology in accordance with ISO 14040 & ISO 14044 [7], [8], although it places serious restrictions on the flexibility of the methodology and, in determining the GHG, concentrates only on environmental impact category. In addition, the method of calculation used provides clear specifications with regard to the system boundary for the inventory, on allocation of by-products and the CO_2 characterisation factors to be used for estimating effectiveness. In the case of the calculations which were implemented, the calculation covers the entire product life cycle up to the finished product of methanol. By-products are considered in the context of allocation on the basis of their lower heating value. The effectiveness estimates for the emissions are implemented in accordance with the characterisation factors specified by IPCC in 2001. Infrastructure costs are excluded from the analysis by the RES-D specifications.

The functional unit which applies to the accounting process is defined as 1 kg methanol. All calculations and results are based on this value.

3.2 Results

3.2.1 Greenhouse gas emissions generated by biomethanol production

The GHG emission results of the analysed methanol concepts are influenced mainly by the emissions generated by the production and supply of the specific raw materials they use (natural gas, biomethane from biogas and bio-SNG, synthetic gas from logging residues and/or short rotation coppice) (cf. Fig. 7). For this reason the GHG emissions from the production of these feedstock are first described in detail. In order to observe the influence of these raw materials on the GHG account for the methanol pathways more closely and display them for purposes of comparison on the basis of their varying energy density (biomethane: 36 MJ/kg, syngas: 5,3 MJ/kg, [5], [6]), the results are in each case shown per MJ biomethane or syngas.

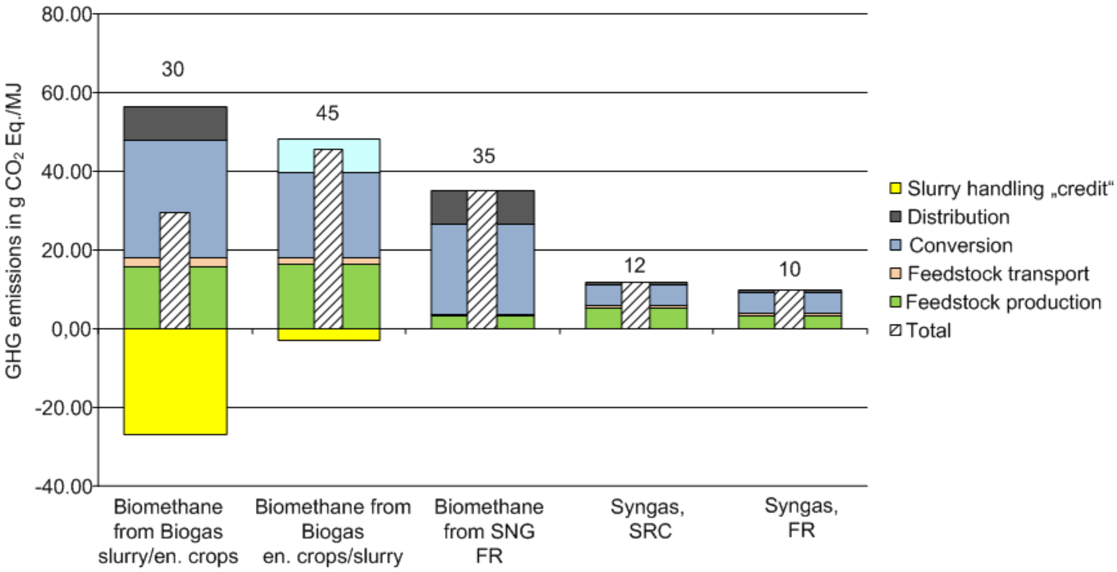

Fig. 6 GHG emissions for various feedstock supply pathways for methanol production on the basis of [5], [6]

The GHG emission values shown indicate a range of 10 g CO_2 Eq./MJ syngas (for the concept of syngas production from logging residues) to 45 g CO_2 Eq./MJ biomethane (for the concept of biogas from energy crops/liquid manure). The results are shown in detail in Fig. 6.

The main cause of this significant difference between the concepts for the generation of biomethane and synthetic gas is the energy-intensive methanation process in order to achieve natural gas quality (contained in the emissions from the conversion process) and the emissions from the cultivation of energy crops (maize silage, grain and grain crop silage) as a biogas substrate. As the concepts designed on the basis of synthetic gas from short rotation coppice and from logging residues do not involve a methanation but rely on synthetic gas with significantly lower energy content, there are no input and emissions resulting from methanisation and conditioning. Thanks to the use of short rotation coppice wood and logging residues, the emissions for substrate generation in the pathways for synthetic biomass gasification are significantly lower than the concepts in which energy crops are used as substrate (biogas). These emissions are for the most part created by the use of fertilisers. To a large extent there is no use of such fertilisers in the supply of logging residues and short rotation coppice wood. As a result, the use of logging residues and short rotation coppice wood generates much lower climate-relevant emissions in supplying raw materials for the thermo-chemical conversion processes than the substrate supplied to biochemical processes for the generation of biogas [5].

Whereas for biomethane from bio-SNG the conversion/biomethane production is the main influencing factor, in the generation of biomethane from biogas both the conversion and the supply of energy crops have an equally large influence on the level of GHG emissions. In modelling the biogas processes for the production of biomethane it was assumed that the digestate was recycled as organic fertiliser for the cultivation of biogas substrates. In this way the use of industrial fertilisers can be reduced in the biomass cultivation process. The relevant substitution effect created by the digestate was calculated with the aid of the TLL [9] calculator for biogas slurry and incorporated into the calculations.

In calculating biomethane production from biogas, a GHG credit was given for the use of liquid manure as a substrate because this avoids conventional liquid manure handling (shown in yellow in Fig. 6). These credits for avoiding liquid manure handling are awarded in response to the avoidance of methane emissions generated by conventional liquid manure storage and spreading. Accordingly the biomethane pathway on the basis of 50% liquid manure represents the most favourable process in this respect.

The results shown indicate the specific emissions from the process of supplying feedstock for the individual concepts for the generation of methanol (cf. Fig. 6). The calculations which were implemented assume raw material input of approx. 37 MJ[1] per kg of MeOH [4], [6] (approx. 34 MJ as raw material input, with approx. 3 MJ as fuel to provide energy for the process).

The overall results of the GHG account for the pathways for methanol production which were analysed are shown in Fig. 7.

[1] This value represents a conservative average of the values shown in the literature (cf. [10], [6], and [11] for example).

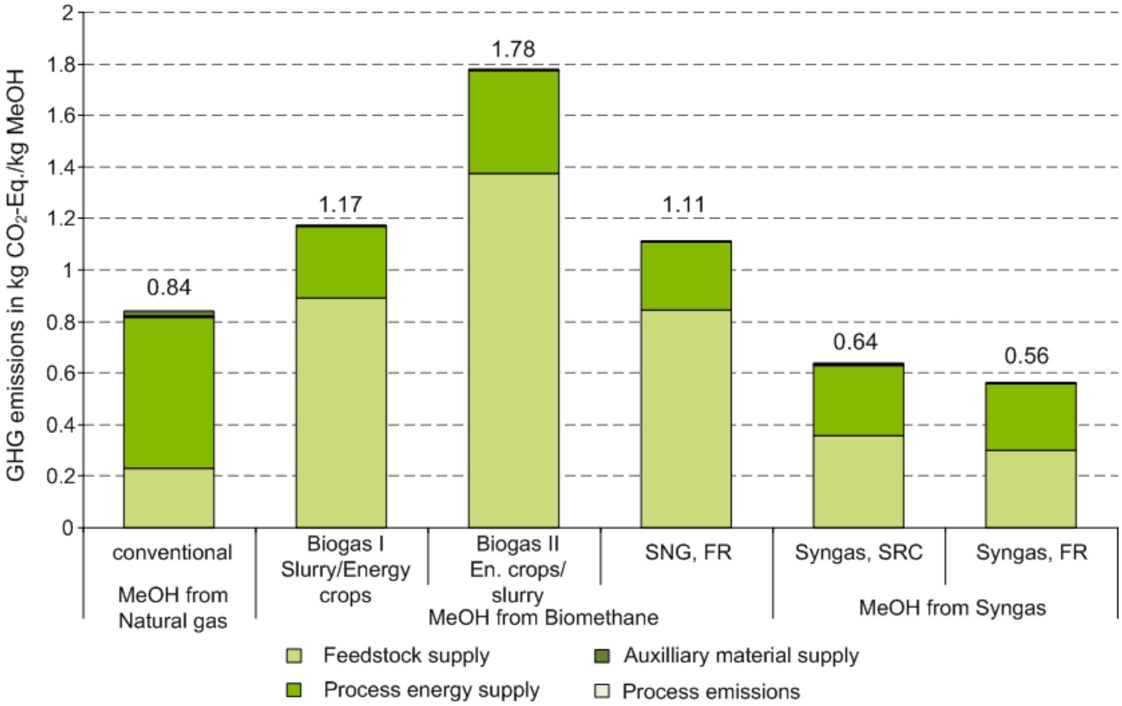

Fig. 7 *The GHG emissions of the various supply pathways for methanol in kg CO_2 Eq./kg MeOH*

The reference pathway for the production of methanol from natural gas generates GHG of 0.82 kg CO_2 Eq./kg methanol. In this context the main causes of emissions are the supply of natural gas at approx. 0.23 kg CO_2 Eq./kg and the supply of process energy on the basis of electricity and partial flow of natural gas at approx. 0.58 kg CO_2 Eq./kg. Compared to this result methanol production from biomethane generates considerably higher CO_2 emissions. The main cause of these higher emissions compared to the reference pathway is the generation of the bio-SNG used as feedstock. The emissions produced by the generation of biomethane amount to approx. 0.84 kg/CO_2 Eq./kg. The energy-intensive treatment in order to achieve natural gas quality as a precondition for feeding into the natural gas network represents a considerable proportion of the overall emissions generated by the production of biomethane. In this pathway the emissions from the process energy supply are significantly lower (approx. 0.26 kg CO_2 Eq./kg) than those of the reference pathway. The reason for this is the use of biomethane as a renewable energy carrier of which a part is used to provide process energy and, together with electricity from the German grid, covers the process energy requirements.

The lowest GHG emissions generated by the methanol pathways which were analysed can be attributed to the two pathways on the basis of synthetic gas produced from short rotation coppice wood and from logging residues (0.64 and 0.56 kg CO_2 Eq./kg MeOH respectively). In these two pathways the main difference compared to the reference pathway can be attributed to the emissions generated by the preliminary stages of the feedstock supply (synthetic gas). In connection with both these concepts it was assumed that the synthetic gas produced is not treated to achieve natural gas quality but is processed directly in the methanol plant. The minor differences between the two pathways are accounted for by the slight differences in the input required for logging residues and short rotation coppice wood respectively as raw materials for synthetic gas.

In these two concepts, too, part of the bio-synthetic gas generated is used to provide energy and, together with electricity from the German grid, covers the process energy requirements. In this process the use of synthetic gas as a source of process energy leads to a significant reduction in GHG emissions in comparison to the use of natural gas for the process energy supply. The results of methanol production from biosynthetic gas are also more favourable than methanol production from bio-SNG. The main reasons for the higher emissions generated by the biomethane pathway on the basis of bio-SNG are once more the comparatively higher emissions created by the supply of the feedstock (bio-SNG production in comparison to synthetic gas production), which result primarily from the input required for purifying the biomethane before it can be fed into the natural gas network.

The highest comparative emissions per kg methanol produced arise from the two concepts based on biomethane from biogas. In this case the high emissions can be attributed mainly to the production of the raw materials (and accordingly to the production of the biogas substrates and the input involved in treating the biogas) (cf. Fig. 6).

3.2.2 Effects of biomethanol used in biodiesel production

Methanol is used in the biodiesel production process for the transesterification of vegetable oils into biodiesel. The emissions generated by the production and use of this auxiliary material also have a recognisable influence on the overall GHG account of biodiesel production.

In order to estimate the possibilities for improving the GHG account of biodiesel through the use of biomethanol, new calculations for the default value of biodiesel from rapeseed were implemented on the basis of the background data for the default values of Germany's Directive on the Sustainability of Biomass (draft version issued in the year 2007) [12]. In the process, the original value, which is based on the use of conventional methanol produced from natural gas for the transesterification process, was compared with newly-calculated values for transesterification on the basis of biomethanol produced from biomethane on the basis of biogas (value for biogas 1 liquid manure/energy crops) and synthetic gas from short rotation coppice wood and logging residues. The results of these calculations are shown in Fig. 8.

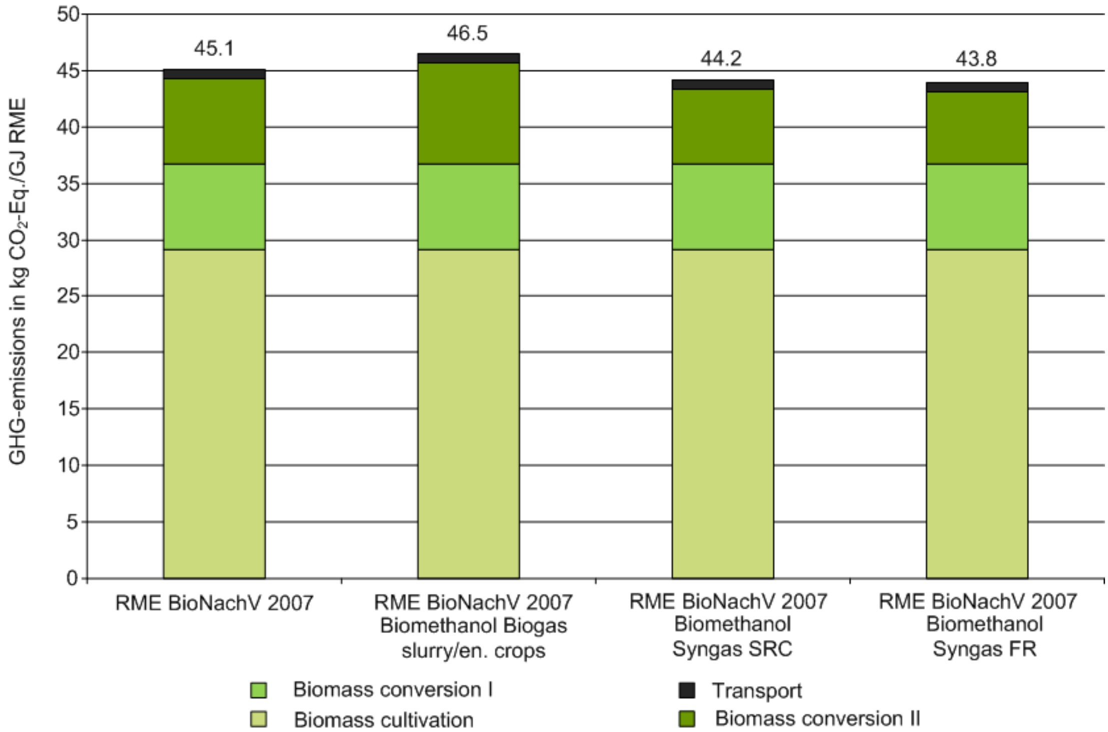

Fig. 8 *Change in the GHG account of biodiesel from rapeseed using biomethanol from synthetic gas, based on [12] and calculations implemented for this study*

The results of the calculations shown in Fig. 8 indicate a GHG savings potential of 2% (biomethanol from synthetic gas generated from short rotation coppice wood) and 3% (biomethanol from synthetic gas generated from logging residues) for the entire biodiesel production chain. Both these relatively minor savings GHG emissions resulting from the use of biomethanol and the possible slight deterioration in the results (because of higher emissions from the preliminary stages of methanol generation, shown here for the pathway for biomethanol from biomethane on the basis of biogas) can, among other factors, be explained by the specifications for calculating GHG emissions for biofuels in accordance with RES-D [1]. The calculation process shown here specifies that the emissions from the combustion of biogenic fuels should be set at zero in the GHG account. This applies initially irrespective of possible fossil content arising from the use of conventionally produced methanol from natural gas. If we look at the GHG accounts of fossil fuels and biofuels (please see for example [13]), it becomes clear that the major proportion of GHG emissions in the fossil fuels account are not released until the point of combustion. In consequence, the possible environmental advantage of biofuels does not arise until after they have been used. For purposes of simplification, it is assumed that in the case of biofuels, the quantity of CO_2, which is bound in during the cultivation of biomass used, will equal the quantity of CO_2, which is released again when these fuels are used.

The result shown therefore only applies to the use of the methanol pathways analysed as an auxiliary material in biodiesel production. If biomethanol is used as a fuel, the result showed in Fig. 7 shifts considerably in favour of the biogenic methanol concepts, because fossil GHG emissions from the combustion process would have to be added to the value shown on the left for methanol generation.

4 ECONOMIC EVALUATION OF BIOMETHANOL PRODUCTION

4.1 Methodology

For the alternative concepts presented for the production of biomethanol the production costs were calculated in addition to the environmental assessment. The calculation was implemented based on the VDI Guideline 6025 "Economic analysis of industrial capital plant and machinery". As shown in Fig. 9 investment is required for the construction of conversion facilities. The second-largest item in the production costs is the input-related cost, which is mainly influenced by the cost of feedstock. In our economic analysis it was assumed that two different types of methanol plant can be applied, depending on the feedstock used. The main difference between these concepts is the additional gasification unit which is required for the treatment of chips from logging residues or short rotation coppice wood (please see Fig. 9). Conditioned biomethane (SNG or biogas) can be processed using conventional methanol technology. The feedstock cost for the methanol plant has been taken from previous studies on the subject of biomethane production [5].

In addition to calculating the cost of producing biomethanol, the study also looked at the impact which the further processing of biomethanol in biodiesel production has on the production costs of biodiesel.

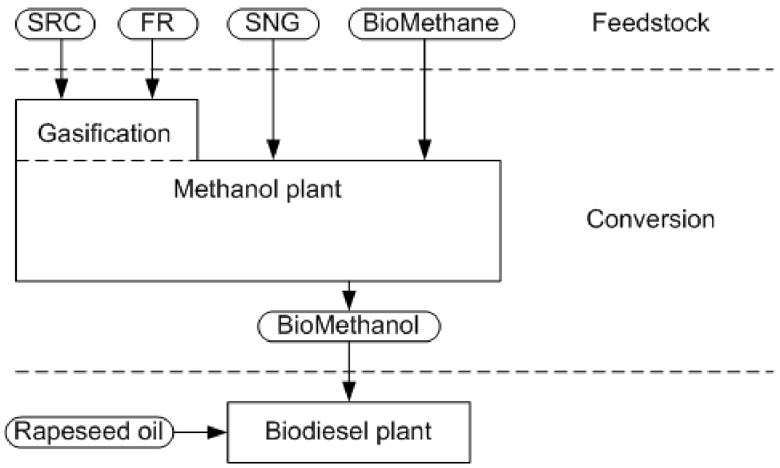

Fig. 9 *Distribution of costs in the ecological analysis of biomethanol pathways*

4.1.1 Capital-related costs

The capital-related costs for the necessary investment were calculated on the basis of annual repayments assuming interest of 7% over a period of 20 years. Table 1 shows the assumed investment costs for biomethanol production from bio¬synthetic gas and for biomethanol production from bio-SNG. The indicated values are based on a study by Hamelinck et al. [14]. The figures differentiate between local gasification of the biomass and whether the methanol production is based on the use of biomethane which is supplied via the natural gas network. In the case of the second option no costs are incurred for the gasification equipment, which means that the investment costs can be reduced considerably.

Table 1 Investment costs for biomethanol facilities in million EUR. [14]

Plant costs	Components	Investment in million EUR	
		SNG MeOH	Syngas MeOH
feedstock pre-treatment			53.1
Gasification	IGT		101.4
	Supply of oxygen		60.7
Gas treatment	Cyclone		1.7
	Heat exchanger		18.9
	Hot gas purification		4.2
Synthetic gas supply	Reformer	34.0	34.0
	Shift-reactors	6.9	6.9
	Selexol-/CO_2-Washer	24.2	24.2
Methanol synthesis	Compressor	15.8	15.8
	Synthesis reactor	12.6	12.6
	Recycle compressor	9.0	9.0
Conditioning		24.7	24.7
Total		127.2	367.2

4.1.2 - Input-related costs

The input-related costs can be attributed primarily to feedstock costs. These were calculated for the varying substrates used in the production of biomethanol. In addition, the cost of auxiliary energy and components such as electricity and water were factored into the input-related costs.

As shown in Fig. 9, biomethane and wood chips were looked at as feedstock in the economic analysis. For this process, biomethane can be supplied from bio-SNG and from biogas. This concept is based on the assumption that the biomethane is supplied to the methane plant via the natural gas network. The calculations for methanol production from wood chips as the raw material and involving the production of a bio-synthetic gas assume that the synthetic gas production takes place in close proximity to the methanol production.

The feedstock costs for the alternative methanol production pathways have been taken from calculations made by the DBFZ as part of a project for FNR (cf. [5]). Table 2 provides an overview of the individual raw material costs and the cost of supplementary materials.

Table 2 cost of feedstock and supplementary materials in methanol production

Input material	Costs	Unit
Biomethane from Bio-SNG	0.11	EUR/kWh
Biomethane from Biogas	0.13	EUR/kWh
Wood chips from logging residues	111.50	EUR/t_atro
Wood chips from rapid-growth plantations	71.20	EUR/t_atro
Electricity	0.13	EUR/kWh
Water	0.50	EUR/m³

The cost of using biomethane covers the entire production chain from the biomass production via its supply to the biomethane plant and right up to the point where the product is fed into the natural gas network. Possible network use charges are not contained in the costs indicated here. The calculation of the biomethane production costs for production from biogas was based on conservative assumptions with regard to the applicable feedstock prices. In relation to current feedstock prices the cost of biomethane production could possibly be lower.

The cost of the wood chips used covers all input right up to delivery to the factory gate. The calculation for the cost of wood chips supplied from short rotation coppice wood assumes an optimised cultivation scenario involving cultivation on a large scale and optimised harvesting technology. Cultivation of wood in this way in short rotation coppice plantations is a realistic prospect for the future, although it is not yet being implemented at present. The production costs calculated for biomethanol production were compared with a current methanol price of 223 EUR/t according to Methanex [15].

4.2 Results

4.2.1 Production costs for biomethanol

The production costs for biomethanol are influenced strongly by input-related costs resulting from feedsock prices

The high production costs of approx. 1,290 EUR/t for the production of methanol from bio-SNG are accounted for by the high overall equipment costs involved in this production process. In this calculation the high equipment costs are reflected in the high input related costs, because an expensive feedstock is used in the form of bio-SNG. The use of biomethane from biogas involves even higher production costs of approx. 1.510 EUR/t. It must be kept in mind here that the biomethane costs were calculated on a conservative basis in terms of agricultural raw material prices. Although in the case of methanol production on the basis of biomethane the investment costs for the methane plants are lower because no gasification is required, as a consequence of the higher production costs for biomethane this concept generates the highest production costs for methanol.

The concept with the most favourable cost level is the production of biomethanol by means of gasification of wood chips from short rotation coppice wood. Provided that the requisite feedstock supply chain can be built up, this would enable the production of biomethanol at a cost of approx. 530 EUR/t.

If wood chips from logging residues are used instead, the production costs are approx. 670 EUR per tonne of methanol. The production costs for the various biomethanol pathways are compared in Fig. 10.

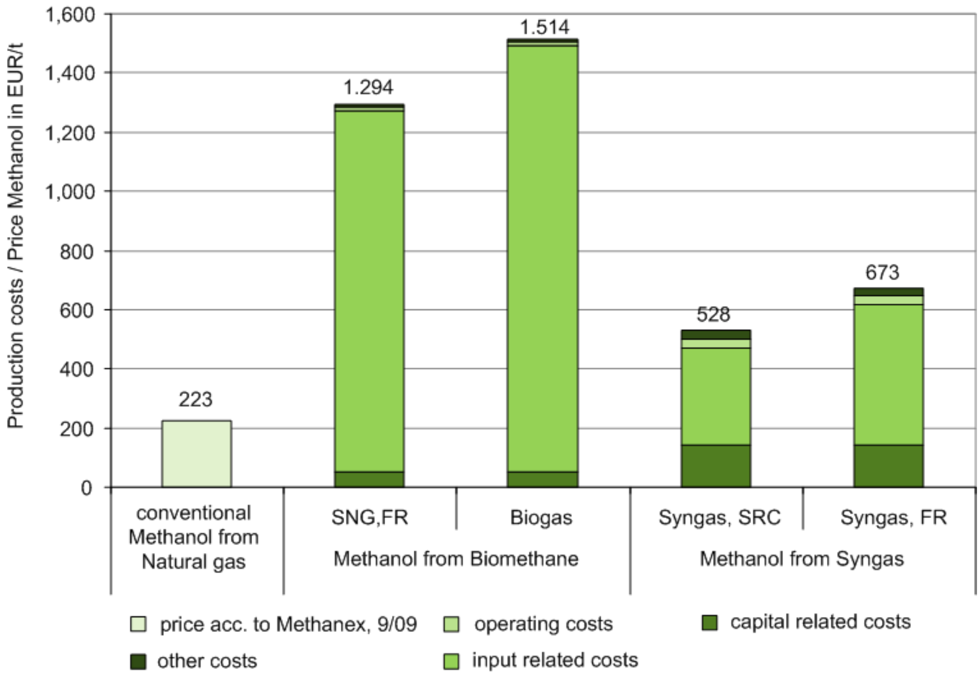

Fig. 10 *comparative production costs for biomethanol in relation to current methanol prices. (Source for methanol prices:[15])*

A comparison of the production costs for biomethanol with the current market price for methanol (on the basis of natural gas) amounting to approx. 230 EUR/t methanol [11] makes it clear that on the basis of the assumptions that are made by this study the production of biomethanol by the concepts which have been looked at is not competitive. Considerable cost savings can be expected if production takes place at a refinery location and if synergies can be implemented from the use of the existing infrastructure. However, such effects are heavily dependent on specific scenarios and have not been looked at in this study.

4.2.2 The effect of using biomethanol in biodiesel production

Because of legal regulations on GHG savings in the production of biofuels, the use of biomethanol for the production of biodiesel may make sense from an environmental point of view. For conventional biodiesel production in a facility with a capacity of 100,000 t/p.a. and vegetable oil prices of approx. 700 EUR/t the resulting production costs are approx. 0.82 EUR/l biodiesel. Of these production costs approx. 2.5 % is accounted for by methanol as an auxiliary material (at a price of 223 EUR/t). If the biomethanol pathways for biodiesel production which have been looked at are applied, the result is biodiesel production costs of 0.84 EUR/l biodiesel for the use of biomethanol on the basis of syngas from short rotation coppice wood, and 0.94 EUR/l biodiesel if biomethanol on the basis of biomethane from biogas is used. Fig. 11 shows the way in which the cost of producing biodiesel is dependent on methanol costs.

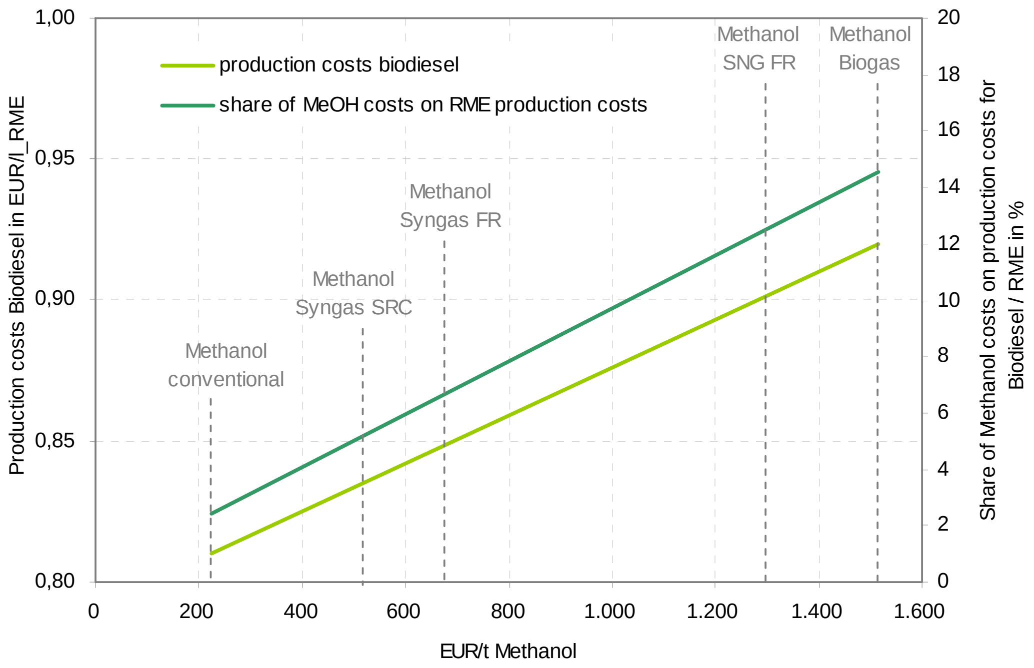

Fig. 11 *Development of production costs and the proportion of methanol as a factor in the cost of biodiesel production in relation to the cost of methanol.*

5 CONCLUSIONS

The calculations which have been made indicate that the use of biomethanol in order to improve the GHG account of biodiesel only makes sense under certain circumstances. Although the use of biomethanol from synthetic gas enables a reduction in approx. 2% to 3% of the GHG emissions generated by the entire biodiesel production chain, because of the higher methanol price this option involves an increase in biodiesel production cost of 6% to 7%. Under this given circumstances the use of biomethanol will not begin to make sense until the legal framework conditions ensure that the fuel-specific GHG emissions have a greater impact on the price of biofuels or that the price is linked to them. The treatment and methanation of biomethane as a feedstock for biomethanol production is basically not necessary in technical terms (to produce biomethanol). The results that have been displayed indicate that this treatment stage has a significant influence on production costs and the GHG emissions of the relevant concepts. Accordingly the direct processing of synthetic gas for methanol production provides the best economic and environmental results within the concepts that have been analysed.

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