Definition of the scenarios and boundary conditions used to investigate the different biofuel production pathways – well to tank

Elaborated by Partners in SP5

1. Introduction

The aim of the RENEW project is to describe, study and evaluate different supply chains of different biofuels, namely DME, Fischer-Tropsch liquids, methane and ethanol.

All the technical and economical data about the different production routes are produced in dedicated subprojects: SP1 to SP4.

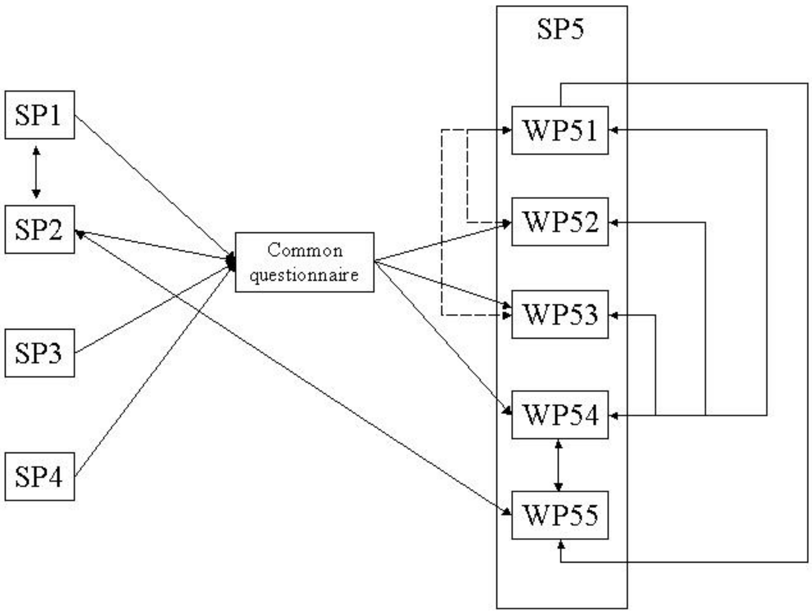
SP1: Optimised fuels for new drive trains

SP2: Optimised process for FT-fuel

SP3: Optimised DME production form black liquor

SP4: Optimisation of bioethanol production

The evaluation is done in SP5: biomass resources and potential assessment is investigated in WP5.1, life cycle assessment in WP5.2, microeconomics and sociopolitical assessment in WP5.3, and technical assessment in WP5.4. Methane is studied in a dedicated work package (WP5.5). To perform these different assessments, information flows look like shown on the following chart.



Within SP5, technical information flows over WP5.4, and information about biomass resources flows over WP5.1.

In order to achieve consistent and comparable results in the different WPs of SP5, all the studied supply chains must:

- investigate the same scenarios with comparable boundary conditions,

- be designed to full fill the same goals with the same background conditions.

Thus, standard boundary conditions and scenarios are defined in the present document. All the biofuel supply chains evaluated in WP5.2, WP5.3, and WP5.4 shall comply with them in order to allow meaningful comparison, and to prevent any deviation from an objective and transparent benchmarking.

This means explicitly that the scenarios described here are investigated from WP5.1, WP5.2, WP5.3, WP5.4. Besides that each WP was free to investigate even more parameter variation and sensitivity analysis than these described in that document.

2. Brief description of the scenarios and basic conditions

In order to achieve consistent and comparable results of the different assessments in SP5, at first a starting point and two different scenarios, which are described below, were planned to be investigated.

Starting point: This starting point describes different production routes for biofuels as they are described today by their developers based on expert-guess and the current frame conditions for biofuel production. This approach establishes a starting point for the scenarios.

Scenario 1 and 2: In those scenarios all the different biofuel supply chains should be built up and organized so that they can be commissioned in 2020. Until this date, further research and development will be performed in the process design and optimisation, and the different industries involved in the supply chain will undergo significant improvements (agriculture, biomass and biofuel logistics, energy industry).

Scenario 1 (Maximized biofuel production): the supply chain is supposed to be as efficient as possible regarding biofuel production. One of the highest criterions of the evaluation is the biofuel production to needed surface area for biomass production ratio. Additional energy input into the production system is accepted even if this available only for single locations.

Scenario 2 (Self sufficient): the supply chain was supposed to be as independent as possible from non-biomass energy sources. One of the highest criterions of the evaluation is the biofuel production to the used non-biomass resource ratio.

The definition of the scenarios to be investigated was not only harmonized within SP5 but also with the other SPs (which means with the technology providers). In this harmonization phase it turned out that the conversion technologies to be investigated are already self-sufficient, which means that from a technological point of view the starting point and the self-sufficient scenario are already the same. Hence, scenario 2 was not investigated in the technical assessment (WP5.4) and in the LCA (WP5.2). However, a sensitivity analyses on the biomass production and provision for the self sufficient scenarios was carried out, because in that case differences between starting point and scenario 2 were identified (WP5.1 and 5.3).

Investigated plant sizes:

For the scenario and the starting point, the biofuel supply chains is virtually scaled up to 500 MW biomass input. This can be realized by one or several plants. The decision whether one plant or several plants with 500 MW biomass input are investigated was made by the respective technology developer. The main design features and technical data were given by the technology developers, and cross validated together with WP5.4 experts through computer models and calculations.

Investigated standard biomass:

Short rotation wood (Willow-salix or Poplar) are investigated as standard woody biomass input.

Additionally, other energy crops species recommended for certain European regions are investigated in the WP5.1 potentials assessment and in the WP5.3 production and provision cost assessment.

Wheat Straw and Miscanthus are investigated as standard herbaceous biomass input.

Only in those cases where the investigated BTL-process is not able or is not designed to convert the above listed biomass input to BTL other biomass inputs (e.g. straw) can be investigated. The chemical and physical property of the standard biomass input is given in the ANNEX, table 1.

The starting point and scenario 1 investigates the following issues, in respect of its time horizon and definition:

- Biomass potential : biomass production yields in Europe
- Agricultural and harvesting technology in Europe
- Background technology : Technology outside the biofuel-plant
- Conversion technology : technology used to convert the prepared biomass to biofuels

The outlines and interactions of these 4 different systems are represented in the following more detailed description of starting point and scenario 1.

3. Description of Starting point and scenario 1 in detail

Starting point

This starting point describes different production routes for biofuels as they are described today based on developers expert-guess and the current frame conditions for biofuel production. This approach establishes a starting point for scenario 1.

Biomass potential:

The average biomass potential of the year 2000-2004 is used in order to avoid annual biomass yields fluctuations. Food and fiber production are affected directly.

Agricultural and harvesting technology:

For agricultural and harvesting technology average data of today (which describe a mix of intensive and extensive cultivation systems) are used.

Background technology:

The average European background technology and energy prices of 2004 are used.

Conversion technology:

The conversion technologies are described in WP5.4, according to the information exchange and technical discussion with the technology owners. It is based on the actual development state of the different technologies. In a nutshell this means "assuming such a plant today would be erected today, what would the plant look like?" The conversion technologies are self sufficient regarding the use of electricity. Thus, no direct external electricity supply is considered for the modelling.

Scenario 1: Maximized biofuel production

In this scenario all the different biofuel supply chains are built up and organized so that they can be commissioned in 2020. Until this date, further research and development will be performed in the process design and optimisation, and the different industries involved in the supply chain will undergo significant improvements: agriculture, biomass and biofuel logistics, energy industry.

The supply chain is supposed to be as efficient as possible regarding biofuel production. One of the highest criteria of the evaluation is the biofuel production to needed surface area for biomass production ratio. Thus, the most important idea of this scenario is to increase the fuel yield. Therefore all carbon of the biomass should be converted into fuel. Due to the low hydrogen to carbon ration of the biomass, extra hydrogen must be added, produced by additional energy input, which is accepted in this scenario. It is assumed that the external energy for hydrogen production will be based on renewable energy (wind power). The use of hydrogen improves the carbon/hydrogen-ration and thus leads to a higher conversion rate of biomass to fuel.

It is clear, that it is not realistic to get wind power until 2020 for more than a small number of conversion plants, but it describes a direction that is worth going, because from an environmental point of view it definitely is to be preferred compared to the production of hydrogen from fossil energy or nuclear power. If there would be the possibility in 2020 for hydrogen from wind power the conversion rate biomass to fuel could be increased. Due to the limited production capacity until 2020 this will not lead to a considerable share of biofuel production. Therefore this scenario does not describe a general improvement option, but an option for special locations or cases.

This scenario is to be understood as only a modelling for rare cases, where hydrogen production from renewables might be possible in 2020.

Biomass potential

The WP5.1 estimation of the highest biomass production yields that can be achieved in Europe in 2020 is used, considering agricultural and forestry intensification. Food and fiber production are affected directly. It is expected that the agricultural policy follows the aim of market liberalization.

Agricultural and harvesting technology

For these production systems WP5.1 expert guess data for agricultural and harvesting technology in 2020 are used. Over the time development of agricultural and forestry technologies, efficiency and capacity is assumed. Intensive agricultural production routes will require high levels of inputs. The forest biomass procurement will be intensified with terms of increased wood felling rates and more intensive forest residues removal compared to the base case.

Background technology:

The WP5.2 and WP5.4 expert guess for European background technology and energy prices in 2020 is based on projections of “European Energy and Transport Trends” published by the EC (ISBN 92-894-4444-4).

Conversion technology:

WP5.4 defined the conversion technologies together with the technology developers according to the following criteria:

1. Conversion technologies will have achieved by 2020 further development, optimisation and automation. Nevertheless, the technical improvements should have already been deeply studied today to be considered as realistic. A sufficient set of data should be made available on these improvements in order to be taken into account in the process modelling work.
2. Conversion technologies shall be designed to maximise the biofuel yield, even if this means an increased use of non-biomass energy sources which are only limited available.

Scenario 2: Self-sufficient: [*]

[*] Since the conversion technologies to be investigated are already self-sufficient, scenario 2 was not investigated in the technical assessment (WP5.4) and in the LCA (WP5.2). However, a sensitivity analyses on the biomass production and provision for the self-sufficient scenario was carried out.

4. Boundary Conditions

1. Definition of input and output streams

Input / Output	**Starting point (= Scenario2)**	**Scenario 1**
Biomass	Biomass can be subdivided into (a) Woody biomass (Forest residues and woody energy crops) (b) Herbaceous biomass (Agricultural residues and herbaceous energy crops) <u>Investigated standard biomass:</u> Forestry wood and willow-salix will be investigated as standard woody biomass input. Cereal straw and Miscanthus will be investigated as standard herbaceous biomass input. Only in those cases where the investigated BTL-process is not able or is not designed to convert the above listed biomass input to BTL other biomass inputs (e.g. straw) can be investigated. The chemical and physical property of the standard biomass input is given in the ANNEX, table 1. Pre-treatment of the biomass is part of the conversion process; properties of the biomass entering the conversion plants should be defined.	
Hydrogen	Hydrogen is produced according to the definition of the plant developers.	Hydrogen is produced on-site via electrolysis based on wind power. (biomass would lead to lower fuel yields, no big potential for hydro, PV might be to expensive). A sensitivity analysis shows the negative environmental effects, if the realistiv and expected electricity mix from UCTE is used. Efficiency and other technical data for the electrolysis are delivered by ESU to all technology partners. Electricity use for H2 is 53.3 kWh/ kg hydrogen. A credit of 0.76883 kWh/ kg Oxgen is given for oxygen sold as a product.
Oxygen	Cryogenic technology	Oxygen from electrolysis (see Hydrogen). Only deficiency oxygen is produced via cryogenic technology
Natural gas	Physical properties LHV= 36,8 MJ/m^3, density= 0.8 kg/m^3	

Solid wastes	The composition of solid wastes is investigated by the plant owners. Plant specific data are used for the assessment. slag: definite quality that allows deposit or marketable as a valuable material (e.g. as roadmaking material) Deposit quality according to TA Siedlungsabfall annex B (see attached file *TA-Siedlungsabfall.pdf*) Amounts of ash and any fraction of entering biomass that has to be segregated (for example fines). Look at consumables : amount of used catalysts and used bed material.
Liquid effluent	Waste water treatment and final discharge according to legislation is part of the investigation. Real plant data of residual pollutant concentration shall be considered. These values have to meet the legal requirements. If not additional waste water treatment within the plant will be necessary. In practice there are no limiting values that can be defined in general, because it depends on regional specific decisions of the authorising agency. In order to have a common basis for the different process routes, one legislation is defined: German "Federal Water Act" (Wasserhaushaltsgesetz - WHG), relevant appendix 22 (chemical industry) and 36 (production of hydrocarbons) → see table 2 extract from the relevant appendixes (see also BREF-document of EU commission on Large Volume Organic Chemical Industry from February 2003, appendix IB)
Gaseous effluent	Real plant data of pollutant emissions should be considered. These values have to be equal or lower as the legal limits, if not→ additional waste gas treatment within the plant will be necessary. Legal limits: see table 3, modelled on German "Technical Instructions on Air Quality" (TA-Luft) and 13. BImSchV (Bundes-Imissionsschutzverordnung) (see also BREF-document of EU commission on Large Volume Organic Chemical Industry from February 2003, appendix IB)
Methanol	Physical properties: 19,50 MJ/kg; ρ= 0,790 kg/m^3
Bio-Methane, SNG (Synthetic Natural Gas)	German regulation DVGW G 260 (Gasbeschaffenheit) clarifies the requirements for Natural Gas in public pipelines such as HHV and relative density. In several European countries specification exist for SNG from biogas (biological production pathway). Unfortunately early 2007 still no regulation is available yet for SNG (Synthetic Natural Gas) form biomass via thermo chemical production pathway. Maximum tolerable concentrations of CO and NH_3 are subject of further discussions with the natural gas industry.
Bio-Ethanol	Standardization of ethanol on European level (not yet passed), working group CEN TC 19 WG21 (TF Ethanol) → ethanol non- denatured as blending component maximum 5% in gasoline (according to EN 228), draft for specifications see table 4
DME	Physical properties: 28,43 MJ/kg at 5 bar 20 ^{o}C ρ=0,668 kg/m^3 , further requirements like allowable content of by products etc. is not defined yet and a preliminary specification was worked out in SP3:

	The results show that high levels (10 w%) of water and methanol in DME has limited impact on the combustion. However the long term effects such as durability etc. was not elaborated. Currently there is ongoing work on standardisation of DME for fuel purposes within ISO. In the production process of DME it is possible to reach levels of 99.999% purity however this high level increases the cost. There is not enough information on the impact on engines of impurities in DME today and further research is needed. The DME that was used in RENEW was of chemical grade with castor oil used as lubrication additive. Lubrication additives are added as well as odour additives in order to detect leakage which could pose a security risk.	
FT fuel	Boiling range according to EN 590	
Electric power produced in the conversion plant	All electric power generated in the conversion plant will be taken for the conversion process or if internally unused electric power (surplus energy) left → will be fed into the grid. The allocation between electricity and heat delivered by the power plant is based on the exergy provided (overall efficiency: 87%, of which efficiency for electricity is 32%).. Electricity generation can be produced via • Purge gases and light paraffins via engine/generator • Process steam via steam turbine • Cooling water inlet data and ΔT according to the legal requirements	
Electric power produced outside the conversion plant	Data for the UCTE electricity mix in 2000 will be used	Wind power is used as a scenario assumption, even if it is available only for a limited number of conversion plants. A sensitivity analysis for the UCTE electricity mix in the year 2020 is investigated
Heat produced in the conversion plant	Heat generated in the conversion plant will be used in the process or if heat surplus is left no usage will be assumed, because adequate use of surplus heat is normally quite difficult.	

2. Definition of conversion plant conditions

physical lifetime	20 years
operating time	8000 h/year

3. Definition of allocation rules

For allocation problems the energy content of the products is used as a generic allocation criteria in all cases were this is possible in order to avoid biased decisions for different allocation problems in the study. For heat and electricity supplied by the power plant, exergy is taken as an allocation criterion. For allocation between wheat grains and straw the price is used as an allocation criteria.

ANNEX

Table 1: Definition of standard lingo-cellulose based biomass (conditions of biomass at plant gate)

Kind of biomass		**Willow-Salix**	**Miscanthus**	**Wheat Straw**
Trading Form		bundles	bales	bales
Particle size [mm]	average	40,00		3*30
	min	20,00		
	max	70,00		
Bulk density [kg dry substance/m³]		200-400	119,00	119,00
Bulk density [kg wet substance/m³]		285-571	148,00	140,00
Proximate analysis [wt % wet]				
Water content	average	30,00	20,00	15,00
Volatiles	average	57,40	65,68	58,70
Fixed Carbon	average	11,25		19,55
Ash content	average	1,40	3,20	5,53
sum proximate analysis				98,78
Elemental analysis [wt % dry]				
	C	48,02	47,04	45,66
	H	6,08	6,14	5,75
	S	0,05	0,19	0,30
	N	0,49	0,67	0,50
	O	43,12	42,24	40,59
Ash content	average	2,00	4,00	6,50
	sum (C, H, O, N, S Ash)	99,78	100,48	99,30
H/C	mol/mol	1,51	1,56	1,50
O/C	mol/mol	0,67	0,67	0,70
Molecular Weight	[kg/kmol waf]			145,07
Ash & Trace Elements				
	Cl [wt % dry]	0,03	0,19	0,7
Trace Components [mg/kg dry]	Al		200	50
	Ca	5000	3500	4000
	Fe	100	600	100
	K	3000	15000	10000
	Mg	500	1700	700
	Mn	97		
	Na		1000	500
	P	800	3000	1000
	Si		15000	10000
	Ti	10		
	As	<0,1	0,1	<0,1
	Cd	2	0,2	0,1
	Cr	1	1	10
	Cu	3	5	2
	Hg	<0,03	<0,02	0,02
	Ni	0,5	2	1
	Pb	0,1	1	0,5
	V		3	3
	Zn	70	25	10
Ash Composition[1] [wt % dry]	SiO2	2,35	33,8	
	Al2O3	1,41	4,3	
	Fe2O3	0,73	2,5	
	CaO	41,2	9,9	
	MgO	2,47	7,6	
	P2O5	7,4		3,6
	Na_2O	0,94	2,2	
	K_2O	15	19,7	0,2
Ash softening point [°C][2]			912	
Ash melting point [°C][2]		1200	1152	
Caloric Values [MJ/kg wet]				
Lower	average	12,16	13,64	13,1
Higher	average	13,46	15,05	14,5

[1] analysis of ash is not connected with trace values

Table 2 extract from German “Federal Water Act” (Wasserhaushaltsgesetz - WHG)

(a) Appendix 36 (Production of hydrocarbons)

C Requirements for waste water at the point of discharge

(1) The following requirements apply to the waste water at the point of discharge into the waterbody:

	Qualified random sample or 2-hour composite sample (mg/l)
Chemical oxygen demand (COD)	120
5-day biochemical oxygen demand (BOD_5)	25
Total nitrogen (as sum of ammonia, nitrite and nitrate nitrogen (N_{tot}))	25
Total phosphorous	1,5
Total hydrocarbons	2

D Requirements on waste water prior to blending

The following requirements shall apply to the waste water prior to blending with other waste water:

	Qualified random sample or 2-hour composite sample (mg/l)	random sample (mg/l)
Adsorbable organic halogens (AOX)	-	0,1
Phenol index after distillation and dye extraction	0,15	-
Benzene and derivatives	0,05	-
Sulphide sulphur and mercaptan sulphur	0,6	-

(b) Appendix 22 (Chemical industry)

D Requirements on waste water prior blending

The following requirements apply to waste water prior to blending with other waste water

	Qualified random sample or 2-hour composite sample (mg/l)	
	I	II
Mercury	0,05	0,001
Cadmium	0,2	0,005
Copper	0,5	0,1
Nickel	0,5	0,05
Lead	0,5	0,05
Total chronium	0,5	0,05
Zinc	2	0,2
Tin	2	0,2

The requirements in column I apply to waste water flows from the manufacturing, further processing or application of these substances. The requirements in column II refer to waste water flows not originating from the manufacturing, further processing or application of these substances but which are nevertheless contaminated with such substances below the concentration levels in column I.

Table 3: Emission limits of waste gas modelled on German "Technical Instructions on Air Quality" (TA-Luft) and 13. BImSchV (Bundes-Imissionsschutzverordnung)

Gasification of biomass – requirements on emission reduction				
		capacity of plant		
	MW	50	250	1000
dust, total	mg/m³	10	5	5
CO	mg/m³	250	250	150
NOx (as NO_2)	mg/m³	250	200	150
SOx (as (SO_2)	mg/m³	350	200	200
H_2S***)	mg/m³	3	3	3
organic material (Ctotal)	mg/m³	100	50	50
NH_3	mg/m³	30	30	30
heavy metals *) single	mg/m³	0,05	0,05	0,01
. . . in sum		0,5	0,5	0,1
dioxine and furane **)	ng/m³	0,1	0,1	0,1

*) metals and their compounds, indicated as metal - Cd, Th, Sb, Cr, Cu, Ni, Co, Mn, V, Zn

**) equivalent of toxicity according to 13. BImSchV

***) only valid for emission mass flows of >15 g/h, below that no concentration limits

Table 4: CEN draft standard for non-denaturated automotive ethanol, as a blending component in gasoline at up to and including 5% (Revision of 17 March 2004)

Property	**Unit**	**Limits**		**Proposed test method**[†]	**Remarks**
		minimum	**maximum**		
Ethanol content + higher saturated alcohols	*% m/m*	98,7		*Regulation EC/2870/2000 – Appendix 2, method B*	- Not denatured. Minimum value is the 100 % minus methanol and water content. - Precision at high ethanol content levels to be established. - Until exact precisions of all methods are not known this calculated value remains.
Higher saturated (C3-C5) mono-alcohols content	*% m/m*		2,0	Regulation EC/2870/2000 – method III or *EN 13132*	- May help to hold water in suspension. - Note for the specification: Problems occur in measuring when gasoline is used as a denaturant. - Precision of all higher alcohols for Method III should be recalculated from raw data. EN 13132 needs precision establishment.
Methanol content	*% m/m*		1,0	Regulation EC/2870/2000 – method III or *EN 13132*	- Precision of all higher alcohols for Method III should be recalculated from raw data. EN 13132 needs precision establishment.
Water content	*% m/m*		0,3	*EN ISO 12937* or *ISO 760*	- Lowest reasonable level desired to lower risk of phase separation. Proposed limits based on Swedish and US experience. - Limit set until the chosen test method allows rounding to 0,01 - EN ISO 12937 and ISO 760 need precision establishment. - ISO 760 (volumetric) is preferred by majority of ETF experts
Inorganic chloride content	mg/L		20	ISO 6227	- Acidity, corrosion in DISI engine injection system. Based on 1 ppm total requirement of US industry - Preferred above total chlorine
Copper content	mg/kg		0,1	*flameless AAS (ASTM D 6723 adapted)*	- Catalyses gum formation Data supporting 0,07 % to be delivered by engine manufacturers. - Investigations on and adaptation of methods is necessary.

[†] Methods in italics need laboratory work or even technical (re)consideration by a CEN/TC 19/WG or TF

		Limits			
				or *XRF method* *(ASTM D 6443 adapted)*	
Total acidity (expressed as acetic acid)	*% m/m*		0,007	*ASTM D 1613*	- Determines weak acidity. Limited to prevent materials corrosion at a longer stage (durability). - Requirement should read as in EN 228: "acidity of ethanol used as a blend stock shall not exceed 0,007 % (*m/m*) (as acetic acid) when tested in accordance with ASTM D 1613." - Method should be investigated for pure ethanol and precision.
pHe		6,5	9,0	ASTM D 6423	- Fuel pump damage if <6,5, materials damage if >9,0. - Determines strong acidity. Limit to prevent materials corrosion. - Further information may relax the lower limit
Appearance		Clear and bright		Visual inspection	- As in EN 228
Phosphorus	mg/L		0,5	*ASTM D 3231 adapted* *or* *EN 14107 adapted*	- Prohibited in EN 228. Limit of detectibility by method. - No detection method seems feasible, due to serious doubts about precision at such low level. - Should WG 21 decide it should be tested, further investigations on and adaptation of methods is necessary.
Involatile material	mg/100ml		10	*Regulation EC/2870/2000 – method II*	- Preferred above solvent washed gum. - Precision of this evaporation method needs to be established
Sulfur	mg/kg		10	*EN ISO 20846* or *EN ISO 20884*	- Property included for ecological message. Methods not adapted to ethanol. - Investigations on and adaptation of methods is necessary. - Correlation towards GC-SSD (specific sulfur detector) method, which is common use in the ethanol industry, is helpful.

Note : Where denaturing of the automotive ethanol is required, the only denaturants permitted are: Automotive gasoline conforming to European Standard EN 228, Ethyltertiobutylether (ETBE), Methyltertiobutylether (MTBE), Isobutanol, Tertiary Butyl Alcohol (TBA).
Any or all of these denaturants may be used alone or together, except Isobutanol which is easily removed, so it is advisable to use it in combination with another denaturant. The quantity(ies) of denaturant(s) is(are) to be decided by national authorities.