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DESCRIPTION

The invention relates to a device and a method for synthesis of aliphatic alcohols, in particular bioethanol.

Bioethanol is produced from renewable raw materials and is used in the fuel sector. Bioethanol can be produced from a variety of plants and plant parts: from plants that contain sugar such as sugar beets and sugar cane, from plants that contain starch such as grain, potatoes and corn, as well as from raw materials that contain cellulose such as wood.

To produce bioethanol, the carbohydrates contained in the plants are fermented with the help of enzymes or yeast to form alcohol. Conventional processes have been in practice for a long time for synthesis of bioethanol from plants containing sugar and starch.

In order for bioethanol fuel to make a reasonable contribution to the energy economy, the production process must have a positive energy balance. The renewable and CO<sub>2</sub>-neutral raw material of the biomass constitutes the main portion of the primary energy expended (input).

The greenhouse gas carbon dioxide is released in fermentation of raw materials and in combustion of bioethanol. However, since the same amount of carbon dioxide from the atmosphere is bound by photosynthesis in the growth of the raw material plants, these chemical processes (photosynthesis, fermentation, combustion) are therefore CO<sub>2</sub>-neutral on the whole. Since additional energy is required in the production of raw materials and in the synthesis of ethanol, the production process is not CO<sub>2</sub>-neutral or even climate-neutral on the whole.

Foods, animal feed and fertilizers are formed from plant constituents, such as protein, plant fibers and fats that are not required to produce ethanol. Grain pulp is high in nutrients and when dried is marketed as animal feed having a high protein content ("dried distillers grains and solubles" = DDGS). Thus one kilogram of protein feed is also formed in the production of one liter of

bioethanol from grain. Vinasse, which remains behind in the fermentation of molasses, is also used agriculturally as an animal feed additive or as a fertilizer.

Another possibility for use of the slurry or stillage is for generating energy by thermal utilization, i.e., combustion, for the purpose of generating steam for the ethanol plant. In addition to lowering the cost of production, this also improves the greenhouse gas balance of the production process. Furthermore, the fermentation of slurry and other residual substances from bioethanol production in biogas systems is of interest from an energy standpoint. The biogas thus produced remains as process heat in the system or is fed into the network. It can be used as an energy carrier like natural gas in households or as a fuel.

A process for utilizing the energy of agriculturally produced raw materials is previously known from DE 10 2007 015 623 A1. In this process the process steam formed in a heating power plant for operation of the steam turbine is used for downstream applications in terms of the process technology such as for a bioethanol plant for production of bioethanol, wherein a portion of the energy contained in the residual steam is rendered usable. In addition, it can also be deduced from DE 10 2007 015 623 A1 that the slurry byproduct of bioethanol production can be used in a biogas production process. This slurry has a high organic content. Therefore it is also highly suitable for biogas production.

In addition, DE 10 2007 001 614 A1 discloses an energy-independent process for production of bioethanol. In this process the thick acid mash separated in a phase separation step is sent to a methanization step that is operated in parallel for the purpose of production of biomethane for the production of process energy in a block heating power plant. In another variant of that process, the condensate from distilled slurry water is used as process water. Furthermore, the bottom product obtained as slurry water should also be at least partially usable for production of process water by using a vacuum circulation evaporating system, a microfiltration technology, ultrafiltration, nanofiltration and/or reverse osmosis and/or membrane technology for

production of process water with a low salt content and concentrate with a high salt content from the slurry water.

DE 10 2010 005 818 A1 discloses a process in which direct recycling of the discharge from the biogas plant for the purpose of forming a mash in the fermenter of a bioethanol production plant is carried out in such a way that the fresh water feed is subject to a substantial reduction, based on the total process. In this process, a substream is separated from the stream of the biogas plant, then purified by means of a membrane process, and the resulting permeate is introduced entirely or partially into the bioethanol production plant for preparing a mash.

Finally, DE 10 2008 058 501 B4 discloses a method for operating a

plant for production of bioethanol, in which the organic waste products of the production process are burned, and the usable heat thereby obtained is recycled back to the plant itself. The usable heat obtained in this way is then consumed in the bioethanol production plant itself, so that there are many possibilities for utilizing heat, whether it is to produce steam or whether it is to directly heat system parts or materials.

US Patent 5,342,702 discloses a system in which ethanol is produced in fermenters and carbon dioxide produced in the fermenters is reacted with hydrogen to form methanol.

Despite recent advances in optimization of the energy demand for production of bioethanol, the processes known in the previous state of the art still have potential for an improved process management with a greater energy efficiency.

The object of the present invention is therefore to provide a device and a method, which will overcome the disadvantages of the state of the art.

The object is achieved by a device according to claim 1 and a method according to claim 6. Advantageous embodiments are defined in the dependent claims.

According to the invention, a system is proposed for synthesis of aliphatic alcohols, comprising:

- at least one first device for biological synthesis of ethanol, wherein carbon dioxide is formed, and
- at least one second device for chemical reaction of the carbon dioxide to form methanol or methane,

wherein the second device for chemical synthesis of methanol or methane is connected downstream from the first device for biological synthesis of ethanol.

The system according to the invention has a second connecting line from the second device to the first device, which makes it possible for water formed in the second device to be introduced into the first device. The water formed in the second device is then used for preparation of the mash.

In addition, the system according to the invention comprises at least one device for generating steam and a third connecting line, wherein the third connecting line is arranged between the device for generating steam and the first device and makes it possible to introduce the steam formed in the device for generating steam into the first device. In doing so, chemically bound energy in the form of hydrocarbons, for example, is supplied to the device for generating steam and is incinerated with oxygen, for example, from pretreated ambient air. For example, oxidization of the pure carbon contained in the fuel with oxygen should be provided here. After incinerating, the result is an exhaust gas mixture containing nitrogen oxide. The free thermal energy can be transferred to demineralized water, forming water vapor, which can be used as a medium for transferring thermal and mechanical energy into additional processes.

Furthermore, the system according to the invention has a fourth connecting line from the first device to the device for generating steam, making it possible to introduce a condensate formed in the first device into the device for generating steam. In the first device, the energy is removed from the water vapor, so that

the water is condensed out and recycled as condensate back via the fourth connecting line to the device for generating steam. Thus, water from the condensate is available to the device for renewed uptake of thermal energy and conversion into water vapor. Due to recycling of the condensate, the water demand as part of the process control is lower due to reuse and effective utilization of the starting materials.

The first device is preferably designed for biological synthesis of ethanol by fermentation. In the biochemical process for synthesis of ethanol under anoxic conditions, ethanol and carbon dioxide are generated from carbohydrates (mainly glucose). In this process, the ability of microorganisms, preferably yeasts, to produce energy by alcoholic fermentation is utilized when the ambient conditions for normal cell respiration are absent.

The second device is preferably designed for catalytic reduction of carbon dioxide with hydrogen.

In catalytic methanol synthesis, methanol and water are obtained from carbon dioxide and hydrogen. The catalyst that is used is not usually particularly active. Improved catalyst properties are achieved by supplying mechanical and thermal energy. After synthesis, crude methanol is available for direct combustion. The reaction of the substance conversion is highly exothermic. The thermal energy can be diverted via the conversion of water to steam. The water formed in the reaction can be used in the system for generating steam or for removal of process wastewaters.

It is additionally preferable for the first device to have a device for separating ethanol. The ethanol is then separated by means of a thermal separation process from the resulting mixture containing alcohol and then absolutized. This results in formation of process wastewater.

More preferably, the second device also has a device for separation of methanol. Methanol can be separated by means of distillative workup. The thermal energy stored in the steam can be used for this purpose.

In another embodiment of the invention, the second device is designed for chemical synthesis of methane. In methane synthesis, methane and water are produced catalytically from carbon dioxide and hydrogen in the Sabatier process. The reaction equation is given as  $\text{CO}_2 + 4 \text{H}_2 \rightarrow \text{CH}_4 + 2 \text{H}_2\text{O}$ . The reaction of the substance conversion is highly exothermic. Thermal energy is derived from conversion of the resulting water to steam.

The system according to the invention preferably has a first connecting line from the first device to the second device, making it possible to introduce a carbon dioxide formed in the first device into the second device. Thus ecologically unobjectionable hydrogen and biogenic carbon dioxide from the first device are available for methanol or methane synthesis. In contrast with the individual application, a green "biogenic" methanol or methane can be produced in contrast with a single application.

The device for generating steam also preferably has a device for separation of nitrogen oxides. The nitrogen oxides formed in combustion of the hydrocarbons and oxygen, supplied in the form of ambient air, for example, are separated here as the exhaust gas.

More preferably, the system according to the invention also includes at least one device for generation of hydrogen, which has a fifth connecting line to the second device, making it possible to introduce the hydrogen into the second device. For example, this permits a supply of hydrogen for chemical synthesis of methanol.

More preferably, the device is also designed for generation of hydrogen as an electrolysis device.

The electrolysis device is also preferably designed for electrolytic generation of hydrogen and oxygen from water. The water used for this process may originate as a condensate from the first device for example or as a product from the second device. By feeding the water formed in the other processes into the electrolysis device and using it for production of hydrogen, optimum utilization of the starting materials within the system is also made possible.



In addition, the electrolysis device is preferably designed as an alkaline electrolysis device or as a PEM electrolysis device. The alkaline hydrolysis uses modular stacks of electrolysis cells. The electrodes are preferably formed from perforated steel plates with the most porous possible surface. The electrodes are preferably positioned as blanks close to the diaphragms and are preferably connected to the end plates (single cell) and/or to the bipolar separating plates (cell stacks) in an electrically conductive manner. Cell frames seal the half-cells preferably to the outside and serve as an embedding medium for the diaphragms. The current source is contacted via the end plates. Both half-cells are preferably flooded with an alkaline electrolyte and then this alkaline solution flows through both of them. The alkaline solution is preferably stored in separate tanks, which serve as gas-liquid separators at the same time. However, the PEM electrolysis cell comprises an anode (oxygen synthesis) and a cathode (hydrogen synthesis), which are separated from one another by an acidic proton exchange membrane (PEM).

More preferably, the system according to the invention has a sixth connecting line, making it possible to introduce the hydrogen formed in the electrolysis device into the device for generating steam. This permits a reduction in the amount of oxygen introduced through ambient air, which in turn minimizes the formation of nitrogen oxides.

As an alternative, the hydrogen is produced by means of biological methods, for example by means of algae or cyanobacteria. In this case the device for generation of hydrogen is preferably a photo bioreactor which contains algae or cyanobacteria.

The subject matter of the invention is also a method for synthesis of aliphatic alcohols, comprising the steps:

- producing a first aliphatic alcohol by means of a biological process, forming carbon dioxide,

- reacting the carbon dioxide thereby formed to methanol or methane by means of a chemical catalytic synthesis.

Conversion of carbon dioxide is carried out downstream from the synthesis of the first aliphatic alcohol and is separated locally from the latter. "Locally separated" is understood here to refer to being contained in different reaction containers, which, however, may be connected to one another through connecting lines. Synthesis of the first aliphatic alcohol and the conversion of carbon dioxide are interconnected in such a way that the carbon dioxide production as a product of synthesis of the first aliphatic alcohol is used at least in part as a starting material for production of a methanol or methane.

According to the invention the first aliphatic alcohol is ethanol.

Synthesis of the first aliphatic alcohol by fermentation by means of microorganisms is preferred, wherein the carbon dioxide formed in fermentation is used as a starting material for the synthesis of the second aliphatic alcohol.

The reaction of the carbon dioxide to form a hydrocarbon by means of essentially known chemical synthesis is carried out in the presence of catalysts and hydrogen to form substituted hydrocarbons (preferably containing oxygen) or unsubstituted hydrocarbons. Synthesis gas is preferably performed as an intermediate step. The composition of hydrocarbons thereby formed is controlled in a known manner by selection of catalysts, hydrogen concentration and the reaction conditions.

In one embodiment of the invention, methanol is used as the hydrocarbon.

The synthesis of methanol preferably takes place by means of catalytic synthesis of hydrogen and carbon dioxide, forming methanol and water. The water can then be used for synthesis of the first aliphatic alcohol, for example.

In catalytic synthesis of methanol, exothermic energy is advantageously released, preferably being dissipated by conversion of water to water vapor.

The thermal energy stored in the form of water vapor can then subsequently be used advantageously for synthesis of the first aliphatic alcohol, for example, for preparation of the mash. This yields efficient energy utilization within the system. Utilization of the thermal energy for separation of the first or second aliphatic alcohol is preferably also conceivable and preferred.

In another embodiment of the invention, the conversion of carbon dioxide takes place by means of chemical synthesis, using methane as the hydrocarbon. After the synthesis, methane is available for direct combustion and/or as a basic chemical. Methane is an important starting material for industrial synthesis of hydrogen, methanol, ethyne, hydrogen cyanide, carbon disulfide and methyl halides. It serves as a starting point for many other organic compounds.

According to the invention, the method additionally comprises a method for generating steam, which is associated with synthesis of the first aliphatic alcohol, such that the steam generated in the steam-generating process is used for input of thermal energy for the synthesis of the first aliphatic alcohol. The steam generated in steam generation is formed, for example, from water that is evaporated by combustion of carbonaceous compounds with oxygen. The thermal energy stored in the form of water vapor is then used preferably for preparing the mash, for temperature regulation in synthesis of the first aliphatic alcohol and/or for separation of the first and/or second aliphatic alcohol. Due to the generation of steam, a medium suitable as a transfer medium for thermal and mechanical energy is available that can be used for additional processes in the system.

More preferably, the method for generating steam additionally includes the separation of nitrogen oxides. Nitrogen oxide compounds are formed in the combustion of oxygen, which is used in the form of ambient air for combustion, for example. These can be separated and discharged as exhaust air in order to prevent them from being introduced into the system.

More preferably, the method additionally includes a method for generation of hydrogen, which is associated with the synthesis of the second aliphatic alcohol, such that the hydrogen thereby generated serves as the starting material for

chemical synthesis of the second aliphatic alcohol. The process for generation of hydrogen is a process based on electrolysis. In addition, the process for generation of hydrogen is a process based on electrolysis, selected from alkaline electrolysis and PEM electrolysis.

Alkaline electrolysis preferably uses modular stacks of electrolysis cells. The electrodes are preferably formed from perforated steel plates with the most porous possible surface. The electrodes are preferably positioned as blanks close to the diaphragms and are connected to the end plates (single cell) and/or the bipolar separating plates (cell stacks) in an electrically conducting manner. Cell frames preferably seal the half-cells from the outside and serve as an embedding medium for the diaphragms. The current source is preferably contacted via the end plates. Both half-cells are preferably flooded with an alkaline electrolyte and/or have this alkaline fluid flowing through them. The alkaline fluid is preferably stored in separate tanks, which serve as gas-liquid separators at the same time.

However, the PEM electrolysis cell comprises an anode (oxygen production) and the cathode (hydrogen production), which are separated from one another by an acidic proton exchange membrane (PEM).

In addition, the process for generation of hydrogen is a process based on electrolysis of water. In this process, oxygen is also formed in addition to hydrogen by electrolysis. This oxygen is used for the steam generation process, so that the amount of oxygen, which is used in the form of ambient air for combustion, is minimized or completely replaced. Depending on the design, this oxygen may replace air completely or partially as the oxidizing agent. This reduces the inert gas content. The energy demand for heating these constituents to the ignition temperature of the fuel is eliminated. The fuel demand is reduced. The efficiency of steam production is increased. Another effect is manifested due to the limitation of the nitrogen input. The amount of nitrogen input for each mol of oxygen introduced from electrolysis is reduced from 3.76 mol to max. zero. There is thus a substantial reduction in the nitrogen oxide content of the combustion exhaust gas.

Alternatively, the hydrogen is synthesized by means of biological processes, preferably by algae or cyanobacteria.

More preferably, the water formed in the synthesis of the second aliphatic alcohol is used for the process for generation of hydrogen. Therefore, the demand for water for electrolysis can be reduced.

Also preferably, all the wastewater streams generated in the process are preferably collected via the synthesis of the first aliphatic alcohol. Therefore, the wastewater streams can be used more economically.

The process according to the invention is characterized by the coupling of a first biological process for synthesis of the first aliphatic alcohol and the second chemical synthesis process for synthesis of methanol or methane, wherein CO<sub>2</sub>, as the product of the first synthesis process, is used as the starting material for the second synthesis process, at least in part. In addition, the process also comprises a process for generating steam, wherein the steam thereby generated serves as a transfer medium for the thermal and mechanical energy for the process. Furthermore, the process may also advantageously comprise a process for generation of hydrogen, which can then serve as the starting material for chemical synthesis of the second aliphatic alcohol.

For the implementation of the invention, it is also expedient to combine the aforementioned preferred embodiments and designs with one another. Preferred refinements of the invention are derived from the combinations of claims or from individual features thereof.

The invention will be explained in greater detail below on the basis of a few exemplary embodiments and the respective figures. These exemplary embodiments should describe the present invention without restricting it.

In the drawings:

Fig. 1 shows a schematic diagram of a system according to a first embodiment of the invention,

Fig. 2 shows a schematic diagram of a system according to a second embodiment of the invention and,

Fig. 3 shows a schematic diagram of a system according to a third embodiment of the invention.

Fig. 1 shows as an example a system 1 according to a first embodiment of the invention. The system 1 according to the invention comprises a device 2 for biological synthesis of a first aliphatic alcohol 4 and a device 3 for chemical synthesis of a hydrocarbon 5, such as a second aliphatic alcohol. The first aliphatic alcohol 4 is ethanol and the second aliphatic alcohol 5 is methanol. The ethanol 4 may be formed by means of alcoholic fermentation by microorganisms. To do so, carbohydrates 6, such as glucose, are introduced into the device 2 along with water 7 under suitable conditions. Because of the alcoholic fermentation, carbon dioxide 8 is also formed in addition to ethanol 4. This carbon dioxide 8 is used according to the invention for chemical synthesis of the methanol 5 in the second device 3. For synthesis of methanol 5, hydrogen is also introduced into the device 3 in addition to carbon dioxide 8 and is converted catalytically to methanol 5 and water 11. The methanol 5 thus formed can then be separated by means of a device, which is not shown in greater detail here. This can take place by distillation, for example. Water 11 is then introduced into the first device 2 for the alcoholic fermentation and is thereby utilized. In addition, the water 11 also functions as an energy medium because it has absorbed the thermal energy released by the exothermic reaction of methanol synthesis. This thermal energy can then in turn be utilized for alcoholic fermentation in the first device 2.

In another embodiment, a system 1 according to the invention is shown in Fig. 2 according to a second embodiment as an example. The system 1 corresponds to the system described above, but the system 1 now has a device for generating steam 12. In the device for generating steam 12, carbonaceous compounds 16 are burned with a supply of oxygen 13. The oxygen 13 can be supplied as ambient air, for example, to the device for evaporation 12. Nitrogen oxides 17, which are separated and discharged separately, are formed in this

combustion. The thermal energy thereby produced is transferred to the water 14, which is supplied to the device 12, so that it is evaporated and supplied to the first device 2 as water vapor 7. Thermal energy contained in the water vapor is used in the device 2 for temperature regulation, for example, or for preparation of the mash, wherein the thermal energy is withdrawn from the water vapor 7, for example, by means of heat exchangers. Consequently, condensation occurs and the condensate 15 thereby formed is sent to the steam generator for renewed evaporation. At the same time, it is also conceivable for the water 11, which is formed in methanol synthesis in the second device 3, to be supplied to the device for generating steam 12.

In another embodiment, a system 1 according to a third embodiment of the invention is shown as an example in Fig. 3. The system 1 corresponds to that described above, wherein the system also comprises a device for generating hydrogen. Therefore, the hydrogen 10 need no longer be supplied separately to the second device but instead can be generated in the system 1. The hydrogen 10 is formed by means of electrolysis of water 14, for example, so that oxygen 13 is also formed in addition to hydrogen 10. This oxygen 13 can be used for combustion of the carbonaceous compounds 16 in the device for generating steam 12. This reduces the inert gas content. The energy demand for heating these constituents to the emission temperature of the fuel is eliminated, so the need for fuel is reduced. The efficiency of steam generation is thereby increased. Another effect is manifested by the limitation on the nitrogen input. The amount of nitrogen input for each mol of oxygen introduced from electrolysis drops from 3.76 mol to max. zero. The nitrogen oxide content in the combustion exhaust gas is also reduced significantly. Furthermore, water 11 formed in methanol synthesis can be used for electrolysis in the device for generating hydrogen 16.

In another exemplary embodiment, which is not shown in greater detail here, the device 3 is designed for chemical synthesis of a hydrocarbon 5 to form methane. In the methane syntheses, methane 5 and water 11 are produced from carbon dioxide 8 and hydrogen 10 by catalytic reaction in the Sabatier process. The reaction formula is:  $\text{CO}_2 + 4\text{H}_2 \rightarrow \text{CH}_4 + 2\text{H}_2\text{O}$ .

In another exemplary embodiment, the theoretical mass flows of the system 1 according to the invention in the formation of ethanol and methanol have been calculated.

The following stoichiometric calculation presents a theoretical ratio of the mass flows to one another based on a batch size of 1,000 kg carbon dioxide.

EXAMPLE STEAM GENERATION

[0063]

Input		Output	
Oxygen (g)	1,090 kg	Carbon dioxide (g)	1,499 kg
Carbon (s)	409 kg		
	1,499 kg		1,499 kg

EXAMPLE ELECTROLYTE

[0064]

Input		Output	
Water (l)	1,227 kg	Hydrogen (g)	137 kg
		Oxygen (g)	1,090 kg
	1,227 kg		1,227 kg

EXAMPLE ETHANOL SYNTHESIS

[0065]

Input		Output	
glucose [s]	2,046 kg	Carbon dioxide (g)	1,000 kg
		Ethyl alcohol (g)	1,046 kg
	2,046 kg		2,046 kg

EXAMPLE METHANOL SYNTHESIS



[0066]

Input		Output	
Carbon dioxide (g)	1,000kg	Water (g)	409 kg
Hydrogen (g)	137 kg	Methyl alcohol (l)	728 kg
	<hr/> 1,137 kg		<hr/> 1,137 kg

In another exemplary embodiment, Table 1 shows the calculated mass flows in the system for formation of ethanol and methanol. The abbreviation s stands for solid, g stands for gaseous, and l stands for liquid.

Table 1

No	Structural formula	Avg. mol. wt.	State of matter	H <sub>2</sub> (mol %)	N <sub>2</sub> (mol %)	O <sub>2</sub> (mol %)	Ar (mol %)	CO <sub>2</sub> (mol %)	C <sub>6</sub> H <sub>5</sub> O (mol %)	CH <sub>4</sub> O (mol %)	C <sub>2</sub> H <sub>6</sub> O (mol %)	H <sub>2</sub> O (mol %)	misc. (mol %)
01	Carbon, pure	12.01	s	---	---	---	---	---	---	---	---	---	100
02	Air, dry	N <sub>2</sub> , O <sub>2</sub> , CO <sub>2</sub> ,...	g	---	78.08	20.94	0.93	0.03	---	---	---	---	0.002
03	Water, de-mineralized	H <sub>2</sub> O	l	---	---	---	---	---	---	---	---	100	---
04	Carbon dioxide	CO <sub>2</sub>	g	---	---	---	---	100	---	---	---	---	---
05	Water	H <sub>2</sub> O	l	---	---	---	---	---	---	---	---	100	---
06	Water	H <sub>2</sub> O	g	---	---	---	---	---	---	---	---	100	---
07	Oxygen	O <sub>2</sub>	g	---	---	100	---	---	---	---	---	---	---
08	Water	H <sub>2</sub> O	l	---	---	---	---	---	---	---	---	100	---



In another exemplary embodiment, the theoretical mass flows of the system 1 according to the invention are calculated in the formation of ethanol and methane.

The theoretical conversion of the mass ratios is obtained as follows:

Input		Output	
carbon dioxide [g]	845 kg	water [g]	692 kg
hydrogen [g]	155 kg	methane [g]	308 kg
	1,000 kg		1,000 kg

The reaction of the mass conversion is strongly isothermic. The thermal energy is dissipated by the conversion of the resulting water to water vapor. When considered from an energy standpoint, the chemical energy from the hydrogen and the carbon dioxide is converted into chemical energy of methane. This results in losses due to the dissipation of thermal energy. The catalyst used is not usually particularly active. Improved catalyst properties are achieved by supplying mechanical and thermal energy.

In another exemplary embodiment, stoichiometric calculations for a theoretical ratio of the mass flows in the formation of ethanol and methane to one another are presented below based on a batch size of 1000 kg carbon dioxide.

STEAM GENERATION

[0072]

Input		Output	
oxygen [g]	1.909.464 kg	carbon dioxide [g]	1,4992.013 kg
carbon [s]	409 549 kg		
	1.4992.013 kg		2.0131.499 kg

ELECTROLYSIS

[0073]

Input		Output	

water [l]	1.227 648 kg	hydrogen [g]	137 184 kg
		oxygen [g]	1.090 464 kg
	1.227 648 kg		1.227 648 kg

ETHANOL SYNTHESIS

[0074]

Input		Output	
glucose [s]	2.046 kg	carbon dioxide [g]	1.000 kg
		ethanyl alcohol [l]	1.046 kg
	2.046 kg		2.046 kg

METHANE SYNTHESIS

[0075]

Input		Output	
carbon dioxide [g]	1.000 kg	water [g]	409 819 kg
hydrogen [g]	137 184 kg	methane [g]	728 365 kg
	1.137 184 kg		1.137 4 kg

In another exemplary embodiment, the calculated mass flows for the formation of ethanol and methane are shown in Table 2.





REFERENCE LIST

[0077]

- 1 system
- 2 device for biological synthesis of ethanol
- 3 device for chemical synthesis of a hydrocarbon
- 4 ethanol
- 5 methanol or methane
- 6 carbohydrates
- 7 water
- 8 carbon dioxide
- 9 processed wastewater
- 10 hydrogen
- 11 water as a product of the chemical synthesis of hydrocarbon
- 12 device for generating steam
- 13 oxygen
- 14 water
- 15 condensate
- 16 carbonaceous compounds
- 17 exhaust gases containing nitrogen oxide
- 18 device for generation of water



## Patentkrav

1. System (1) til tilvejebringelse af alifatiske alkoholer, omfattende:
  - 5 - i det mindste en første anordning (2) til biologisk fremstilling af ethanol (4), idet der dannes kuldioxid, og
  - i det mindste en yderligere anordning (3) til kemisk omsætning af kuldioxiden (8) til methanol eller methan,
- 10 hvor den yderligere anordning (3) til kemisk syntese af methanol eller methan (5) er placeret efter den første anordning (2) til biologisk fremstilling af ethanol (4), hvor
  - 15 - systemet (1) indbefatter en yderligere forbindelseslinie fra den yderligere anordning (3) til den første anordning (2), der gør det muligt at overføre vand (11), der er dannet i den yderligere anordning (3), til den første anordning (2), hvor vandet (11), der er dannet i den yderligere anordning (3), anvendes til indmæskning,
  - 20 - derudover omfatter i det mindste en anordning (12) til dampfremstilling og en tredje forbindelseslinie, hvor den tredje forbindelseslinie er placeret mellem anordningen til dampfremstilling (12) og den første anordning (2) og gør det muligt at overføre dampen (7), der er dannet i anordningen til dampfremstilling (12), til den første anordning (2), og hvor
  - 25 - systemet (1) indbefatter en fjerde forbindelseslinie fra den første anordning (2) til anordningen til dampfremstilling (12), der gør det muligt at overføre et kondensat (15), der er dannet i den første anordning (2) til anordningen til dampfremstilling (12).
- 30 2. System ifølge krav 1, kendetegnet ved, at systemet (1) indbefatter en første forbindelseslinie fra den første anordning (2) til den yderligere anordning (3), der gør det muligt at overføre kuldioxiden (8), der er dannet i den første anordning (2), til den yderligere anordning (3).

3. System ifølge et af kravene 1 eller 2, der desuden omfatter i det mindste en anordning til generering af hydrogen (16), der indbefatter en femte forbindelseslinie til den yderligere anordning (3), der gør det muligt at overføre hydrogenen (10) til den yderligere anordning (3).
- 5
4. System ifølge et af de foregående krav, kendetegnet ved, at anordningen til generering af hydrogen (16) er udformet som en elektrolyseanordning.
5. System ifølge et af de foregående krav, kendetegnet ved, at systemet (1)
- 10 indbefatter en sjette forbindelseslinie, der gør det muligt at overføre ilten (13), der er dannet i elektrolyseanordningen (16), til anordningen til dampfremstilling (12).
6. Fremgangsmåde til fremstilling af alifatiske alkoholer, omfattende:
- 15
- fremstilling af en første alifatisk alkohol (4) ved hjælp af en biologisk fremgangsmåde, idet der dannes kuldioxid (8), hvor det første alifatiske alkohol (4) er ethanol,
  - omsætning af kuldioxiden (8) til methanol eller methan (5) ved
- 20 hjælp kemisk, katalytisk syntese,
- hvor omsætningen af kuldioxiden (8) er placeret efter fremstillingen af det første alifatiske alkohol (4) og er adskilt stedmæssigt, og fremstillingen af det første alifatiske alkohol (4) og omsætningen af kuldioxiden (8) er
- 25 forbundet på en sådan måde, at kuldioxiden (8) som produkt af fremstillingen af det første alifatiske alkohol (4) anvendes i det mindste delvist som reaktant til fremstilling af methanol eller methan (5), hvor vand (11), der dannes i forbindelse med omsætningen af kuldioxiden (8) til methanol eller methan (5), anvendes til indmæskning under fremstillingen
- 30 af ethanolen (4), og derudover omfattende en fremgangsmåde til dampfremstilling, der er forbundet på en sådan måde med fremstillingen af ethanolen (4), at dampen (7), der genereres ved fremgangsmåden til dampfremstilling, anvendes til indføring af termisk energi til fremstilling af ethanolen (4), og at der tilføres et kondensat (15), der dannes i forbindelse

med fremstillingen af ethanolen (4), til fremgangsmåden til dampfremstilling (12).

7. Fremgangsmåde ifølge krav 6, der desuden omfatter en fremgangsmåde til generering af hydrogen, der er forbundet på en sådan måde med fremstillingen af methanolen eller methanen (5), at den genererede hydrogen (10) tjener som reaktant til den kemiske syntese af methanolen eller methanen (5), hvor fremgangsmåden til generering af hydrogen er en fremgangsmåde, der er baseret på elektrolyse af vand (14), ved hvilken der som følge af elektrolysen foruden hydrogen (10) også dannes ilt (13), der anvendes til fremgangsmåden til dampfremstilling, hvor fremgangsmåden er valgt fra alkalisk elektrolyse og PEM-elektrolyse.
8. Fremgangsmåde ifølge et af kravene 6 eller 7 kendetegnet ved, at der i forbindelse med fremstillingen af methanol eller methan (5) dannes vand (11), der anvendes i fremgangsmåden til generering af hydrogen.

1/3

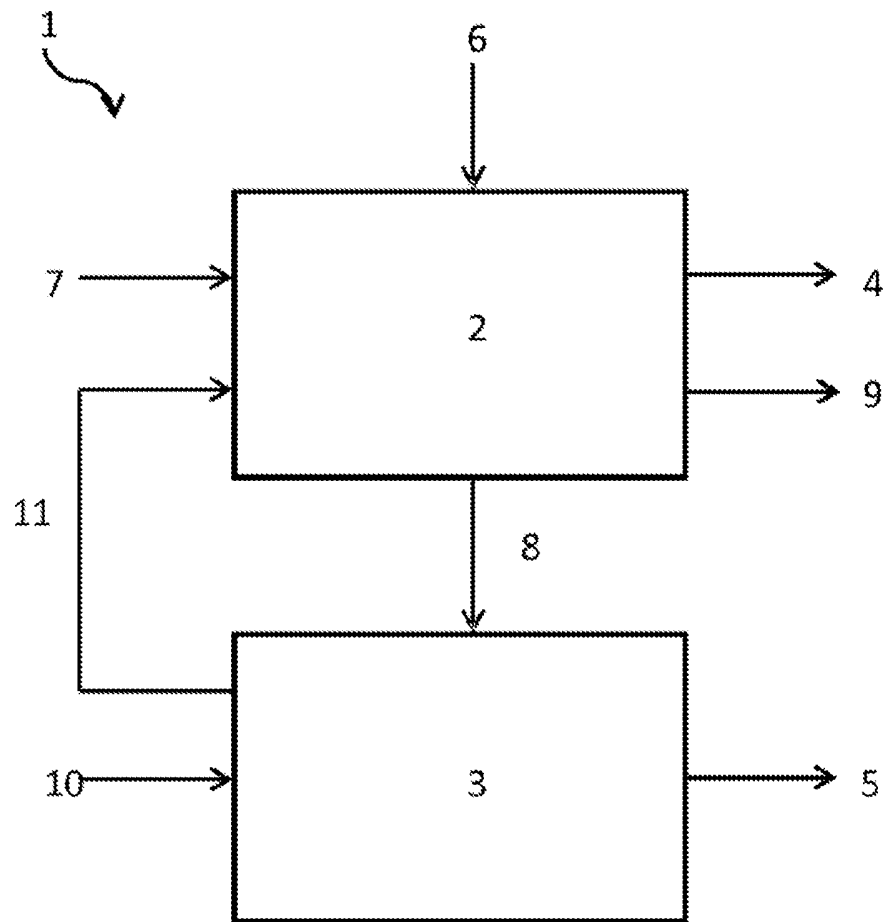


Fig.1

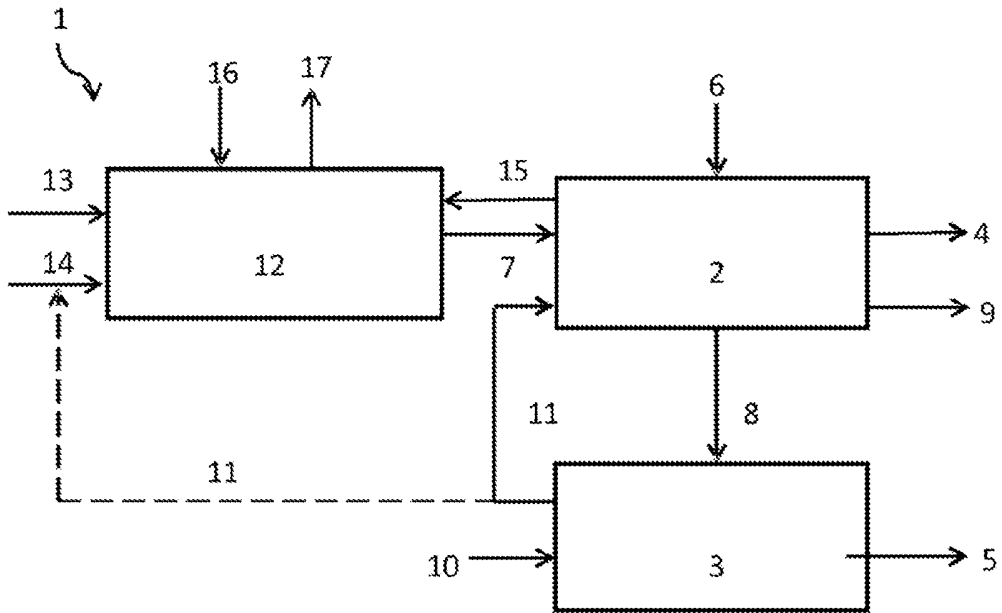


Fig. 2

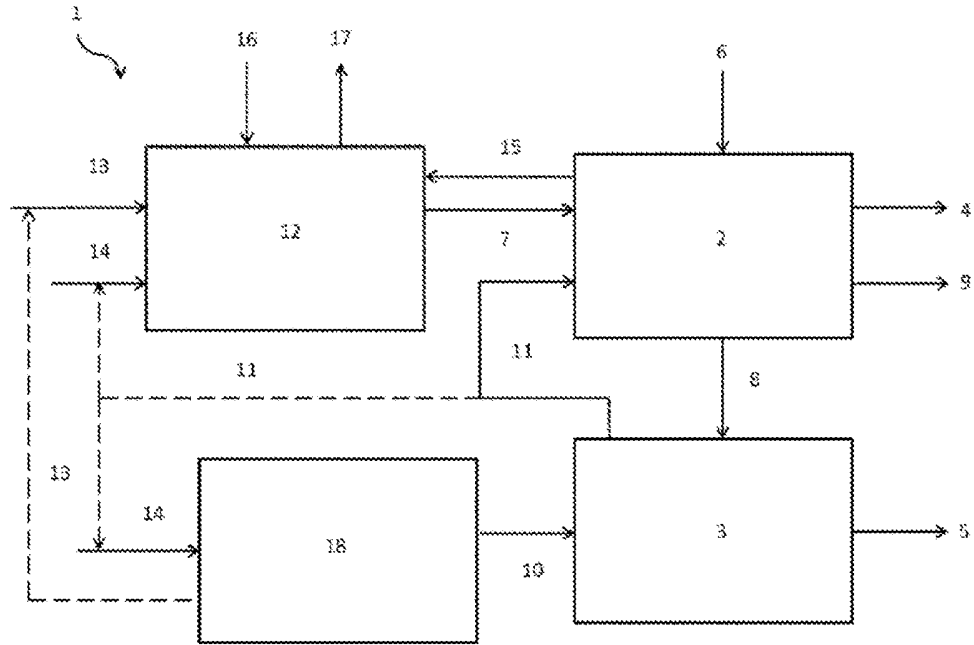


Fig.3