

CLAIMS

1. A waste conversion system, comprising
 - at least one pre-treatment unit for receiving a stream of waste of which
5 at least a portion thereof being organic waste, the pretreatment unit comprising at least one continuous-flow steam explosion reactor;
 - at least one separation unit, for receiving a stream of pre-treated waste
10 from said pre-treatment unit, the separation unit comprising at least one conditioning section and at least one separation section for the separation of conditioned waste into at least one fat/oil component and at least one aqueous component;
 - at least one biodiesel production unit, for generating biodiesel from the
15 at least one fat/oil component;
 - at least one digestion unit, for anaerobic digestion and/or fermentation of the at least one aqueous component; and
 - at least one composting unit, for the generation of compost from solid organic material.
2. The system according to claim 1, wherein said steam explosion reactor comprises a
20 high-pressure retention section and a pressure relief section and wherein said high-pressure retention section comprises at least one adjustable-speed conveyor for transporting said stream of waste through said section.
3. The system according to claim 2, wherein said adjustable speed conveyor is a screw
25 conveyor.
4. The system according to claim 2, comprising a rotational feed valve at the entrance of the high-pressure retention section for feeding said stream into the section and comprising a rotational discharge valve for discharging material from said high-
30 pressure retention section.
5. The system according to claim 4, comprising first steam injection means for injecting steam into a loading compartment of said rotational feed valve prior to its rotation to a discharge position and second steam injection means for injecting steam to a
35 discharge compartment of said rotational discharge valve after it's discharge into the pressure relief section, prior to its rotation back to its loading position.
6. The system according to claim 4 or 5, further comprising a control unit that allows
40 adjustable retention time of material within said high-pressure retention section, by synchronization of the rotational feed valve and the rotational discharge valve and the conveying speed within the high-pressure retention section.

7. The system according to any of claims 2 to 6, wherein the high-pressure retention section of the pre-treatment unit operates at a pressure in the range of about 10 to 40 bar, and at a temperature in the range of about 180-250°C.
- 5 8. The system according to any of claims 1 to 7, wherein said steam explosion reactor is configured for operating as an alkaline steam explosion reactor.
9. The system according to claim 8, wherein said continuous-flow alkaline steam explosion reactor comprises at least one integrated carbon dioxide scrubbing unit.
- 10 10. The system according to claim 9, wherein the alkaline steam explosion reactor comprises a high-pressure retention section and a pressure relief section, and wherein said pressure relief section of the steam explosion reactor serves at the same time as said carbon dioxide scrubbing unit.
- 15 11. The system according to claim 9 or 10, wherein an upper part of the carbon dioxide scrubbing unit is adapted to receive delivery of a stream of material from the high-pressure retention section of the alkaline steam explosion section under an angle with respect to the central axis of the carbon dioxide scrubbing unit, to direct said stream of material into a cyclone patten by means of at least one internal spiral.
- 20 12. The system according to any of claims 9 to 11, wherein the carbon dioxide scrubbing unit further comprises at least one carbon dioxide inlet provided within a lower part of the scrubbing unit, whereby the alkaline stream of material from the high-pressure retention section meets carbon dioxide rich stream to facilitate carbon dioxide scrubbing.
- 25 13. The system according to claim 11 or 12, where the carbon dioxide section comprises two inserted spirals which are vertically offset with respect to each other with the upper spiral having clearance from the inner wall of the scrubber while the lower spiral has no clearance, which effectuates partial velocity component perpendicular to the primary cyclone pattern flow of the stream of waste within the carbon scrubbing unit, effectuated by material conveyed from the upper spiral to the lower spiral along the inner wall of the carbon scrubbing unit.
- 30 14. The system according to claim 13 wherein said lower spiral is provided with a corrugated pattern partly guiding material towards the center of the scrubber and a protruding rim at the inner edge of the spiral causing the perpendicular component of the material to splash and disperse towards the center of the scrubber unit.
- 35 15. The system according to any of claims 10 to 14, wherein the carbon dioxide scrubbing section operates at a pressure in the range of about 1 to about 5 bar.
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16. The system according to any of claims 10 to 15, wherein said scrubber unit is provided with heat exchanging cooling elements providing cooling of the scrubbing media and recovering heat from the steam explosion which is preferably used to pre-heat water fed to the steam boiler of the system .
17. The system according to any of claim 10 to 16, wherein said pressure-relief section serves as a first carbon dioxide scrubber, the system further comprising a secondary scrubber which is fed with a liquid fraction from said first scrubber as scrubbing media and may be run in conventional top-down spraying configuration at elevated pressure or reduced pressure, for receiving the CO₂ lean gas stream from the first carbon dioxide scrubber for further carbon dioxide removal.
18. The system according to any of claims 9-17, further comprising means for directing carbon dioxide that is generated within the system into the carbon dioxide scrubbing unit.
19. The system according to any of the preceding claims, wherein the pretreatment unit further comprises at least one grinding and/or homogenization unit that is arranged upstream of the continuous-flow steam explosion reactor.
20. The system according to any one of claims 1-19, wherein the pretreatment unit further comprises a wetting and mixing section upstream of the continuous-flow steam explosion reactor, for wetting and mixing a stream of waste and optionally adjusting pH of the stream, prior to steam explosion.
21. The system according to claim 20, wherein said wetting and mixing section comprises a chamber with a mixer and at least one armature for introducing water or aqueous solution for wetting and optionally pH adjustment, and a discharge valve for discharging conditioned material.
22. The system according to any of the preceding claims, wherein said separation unit comprises a conditioning section, a continuous fat/oil separation section, a liquid/solid separator, and a centrifugal purifier.
23. The system according to claim 22, wherein said continuous fat/oil separation section comprises:
- a vertically arranged elongated tank,
 - an elongated tube located centrally and coaxially within the elongated tank,
 - a discharge valve arranged at the entry of said tube, by which conditioned material can be discharged from the conditioning section of the separation unit into the tube,

- one or more air injector, near the lower end of the tube, preferably comprising one or more microbubble injector,
 - an exit valve on the tube,
 - means for feeding fat/lipid accumulating on the liquid surface within said elongated tank to a fat/oil buffer tank or the centrifugal purifier,
 - a line for feeding water from the centrifugal purifier to the upper portion of the tank.
24. The system according to any of claims 1-21, wherein said separation unit comprises a centrifugal decanter unit as one instrument comprising a screw conveyor decanter and a disc centrifuge.
25. The system according to claim 24, wherein said centrifugal decanter unit comprises an axial bearing shaft, a decanter house coaxially enclosing said screw conveyor which is rotatable on said axial bearing shaft, at least one stationary centrally positioned main material inlet for feeding material into the screw conveyor, at least one solid matter outlet in proximity to the distal end of said screw conveyor, a disc separator house enclosing said disc centrifuge, at least one impeller arranged between the decanter house and the disc separator house, a heavy phase outlet and a lighter phase outlet.
26. The system according to claim 25, wherein said decanter house and said disc separator house, said screw conveyor and said disc centrifuge are each independently rotatable around the axial bearing shaft.
27. The system according to any of the preceding claims, wherein the biodiesel reactor unit is a continuous-flow reactor, adapted to receive a continuous flow of said fat/oil component and thereby generate a continuous flow of biodiesel.
28. The system according to claim 27, wherein said biodiesel production unit comprises a modular continuous-flow biodiesel reactor that comprises a plurality contact plates coated with esterification and/or transesterification catalyst for catalyzing esterification of free fatty acids and or transesterification of glycerides, spacers, and static mixers for adjusting the spacing between the contact plates and enhancing turbulent mixing between these.
29. The system according to claim 28, wherein said continuous-flow biodiesel production unit comprises a plurality contact plates coated on one side with esterification and/or transesterification catalyst, whereby alternating two coated sides face each other and two non-coated face each other and the reactant media flows between the coated sides of the contact plates while a thermal media for temperature control of the reactants flows between the non-coated sides of the contact plates

- 5 30. The system according to any of the preceding claims, wherein said biodiesel unit accommodates as input either or both of triglycerides and free fatty acids, wherein said unit comprises at least one catalyst that catalyses transesterification of glycerides and at least one catalyst that catalyses esterification of free fatty acids.
- 10 31. The system according to claim 30, wherein said catalyst that catalyses esterification of free fatty acids is arranged in a first section and said catalyst that catalyses transesterification of glycerides is arranged in a second section of the unit.
- 15 32. The system according to claims 27 and 31 wherein said continuous-flow biodiesel unit comprises at least two reactors, both comprising non-coated contact plates, spacers and static mixers, whereby esterification with homogeneous acid catalyst is effectuated in the first and transesterification with homogeneous basic catalyst is effectuated in the second.
- 20 33. The system according to any of claims 28 to 32, wherein said contact plates are corrugated.
- 25 34. The system according to claim 32, wherein purification and water removal is effectuated through flash evaporation and ion exchange between said esterification and transesterification reactors
- 30 35. The system according to any of claims 27 to 34, wherein said continuous-flow biodiesel reactor unit is enclosed within a differential pressure equalizing chamber enabling high-pressure operation of the reactor.
- 35 36. The system according to any of the preceding claims wherein said digestion unit comprises at least one first unit configured for methane production and at least one second unit for ethanol production.
- 40 37. The system according to any of claims 1 to 35, wherein said digestion unit comprises at least one unit that is configured so that it can accommodate methane production or ethanol production depending on the choice of a user and available waste stream material.
38. The system according to any of the preceding claims, wherein said composting unit comprises an initiation section comprising at least one screw conveyor and at least one feed port for feeding into the section material from the separation unit, and a discharge port, an incubation section that comprises a chamber with humidification sprayers arranged in proximity to the chamber top, and means for providing forced

aeration at least in proximity to the bottom of the chamber, which are preferably air nozzles connected to pressurized air.

5 39. The system according to claim 38, wherein said initiation section comprises at least two parallel compartments each comprising a conveying mixer that agitates material in the respective compartment and at least partially conveys material to the other compartment.

10 40. The system according to claim 38 or 39, comprising at least one screw conveyor for transporting substrate from the initiation section to the incubation section, the screw conveyor having an increase in diameter along the conveying direction in the range of about 20-50%, enabling addition of bulking material during the transport of the substrate from the initiation section to the incubation section.

15 41. The system according to any one of the preceding claims, wherein the system is energy self-sufficient, such that the system, during operation, does not require external sources of energy.

20 42. The system according to any of the preceding claims, further comprising a rendering unit upstream of the pre-treatment unit, wherein said rendering unit is configured to separate from the incoming waste stream at least a portion of a fat/oil component of said waste, and directing said separated portion of fat/oil component to said biodiesel unit bypassing said pre-treatment unit.

25 43. The system according to claim 42, wherein the separation section of the rendering unit comprises said centrifugal decanter unit as one instrument.

30 44. The system according to any one of the preceding claims, further comprising at least one steam generator, for providing steam within the system, which is preferably a combusting steam generator fed with source fuel generated in the system.

 45. A process for treating and converting waste, comprising

35 - receiving a stream of waste which comprises at least a portion that is organic waste,

 - introducing the stream of waste or at least a portion thereof into a wetting and mixing section and wetting and mixing the waste,

 - transferring the stream from said wetting and mixing section into a continuous-flow steam explosion reactor and subjecting it to steam explosion treatment,

40 - directing a stream of waste treated in said steam explosion reactor to a separation unit, and separating the pre-treated waste stream into at

least a component comprising fat and/or oil, a component comprising aqueous slurry of organic matter, and a component comprising wet solid organic material,

- introducing said fat and/or oil component into a biodiesel production unit, and generating biodiesel from said fat/oil component,
- introducing said component comprising aqueous slurry into a digestion and/or fermentation unit and digesting and/or fermenting said component through anaerobic digestion and/or fermentation,
- introducing said component comprising wet solid material into a composting unit.

46. The process according to claim 45, wherein said steam explosion treatment is conducted at a pressure in the range of about 10 to 40 bars.

47. The process according to claim 45, where said steam explosion treatment is conducted at a temperature in the range of about 180 to about 250°C.

48. The process according to any of claims 45 to 47, wherein the stream of waste is subjected to steam explosion treatment in a high-pressure relief section, from which the stream of material is transferred to a pressure relief section through a rapid release of pressure.

49. The process according to claim 45 wherein the stream of waste is mixed with alkaline aqueous solution in the wetting and mixing section.

50. The process according to claim 49, wherein after the steam explosion treatment the stream of waste is utilized as scrubbing media for carbon dioxide scrubbing in a carbon dioxide scrubbing section integrated with said pressure relief section.

51. The process according to claim 50, wherein the stream of waste is subjected to steam explosion treatment in a high-pressure retention section from which the stream of material is transferred to a pressure relief section through a rapid release of pressure, where said stream is used as scrubbing media for removal of carbon dioxide from the carbon dioxide rich methane stream from the anaerobic digestion, and/or from other carbon dioxide rich gas streams emerging from the process.

52. The process according to any of claims 50 to 51, comprising transferring said stream from said high-pressure retention section into said pressure relief section and scrubber unit such that the flow of the stream enters at an angle with respect to the central axis of the scrubber unit, such that the stream of material flows substantially along at least one spiral arranged in said scrubber unit in order to create a cyclone type flow pattern, and

introducing said carbon dioxide into said scrubber unit through at least one inlet provided within a lower part of the scrubbing unit.

5 53. The process according to any of claims 50-52, comprising providing said carbon dioxide scrubbing section with carbon dioxide generated in downstream steps of the process.

10 54. The process according to any of claims 50-53, further comprising cooling substrate in said carbon dioxide scrubbing section with heat-exchange cooling elements thereby recovering heat from the steam explosion section and preferably use the heat-exchange cooling elements to pre-heat water for a steam boiler of the system.

15 55. The process according to any of claims 50-54, further comprising discharging liquid material from said scrubbing unit to a secondary scrubber section which is preferably operated in a top down spraying configuration at elevated pressure and reduced temperature, and feeding into said secondary scrubbing section the exhaust from the primary scrubber for removal of residual carbon dioxide still remaining after the primary scrubber.

20 56. A process for treating and converting waste, comprising

- receiving a stream of waste which comprises at least a portion that is organic waste,
- 25 - introducing the stream of waste or at least a portion thereof into a rendering unit,
- subjecting said stream in said rendering unit to heating at a temperature range of about 80-100°C, and preferably in the range of about 90-95°C,
- separating the material that has been heated into a fat/lipid fraction and a fraction comprising solid materials, and runoff aqueous solution,
- 30 - transferring said fraction comprising solids material into a continuous-flow steam explosion reactor, subjecting it to steam explosion treatment,
- optionally transferring a stream of waste treated in said steam explosion reactor to a separation unit, and separating the steam explosion treated waste stream into at least a component comprising fat and/or oil, a
- 35 component comprising aqueous slurry of organic matter, and a component comprising solid organic material,
- introducing said fat and/or oil component from the rendering unit and optionally a fat and/or oil component from the separation unit, into a biodiesel production unit, and generating biodiesel from said fat/oil
- 40 component,

- introducing said aqueous slurry into a digestion and/or fermentation unit and digesting and/or fermenting said component to methane and/or ethanol, respectively,
- introducing said component comprising wet solid material into a composting unit.

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57. The process according to any of the claims 45-56, wherein said step of separating in the separating unit comprises feeding material into a separation tank of an oil/fat separation section, delivering microbubbles to said separation tank, removing fat and oil that accumulates on the liquid surface within said separation tank, and feeding aqueous slurry from said separation tank to a liquid-solid separator, feeding from said liquid-solid separator a fraction comprising wet solids to said compositing unit, and feeding an aqueous fraction that is high in organic material content to a collection tank or to an anaerobic digestion unit and/or fermentation unit.

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58. The process according to claim 57, wherein said aqueous slurry fed to said liquid-solid separator is subjected to a compressing screw conveyor embedded in a slanted cylindrical housing, the aqueous slurry being fed into the screw conveyor at a lower end of said cylindrical housing, the screw conveyor conveying solids material upwardly through said cylindrical housing towards an exit port for the fraction comprising solids.

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59. The process according to any of claims 45 to 56, wherein said step for separating comprises feeding said pre-treated waste stream to a centrifugal decanter unit, comprising feeding said stream through a central axial inlet to a screw conveyor in a rotating decanter house, conveying solids with said screw conveyor towards a solids outlet, forcing liquid through an impeller to a disc separator house enclosing a disc centrifuge, rotating said disc centrifuge and said disc separator house to thereby separate a heavy liquid aqueous phase and a light liquid fat and/or oil phase, directing each phase to a respective outlet.

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60. The process according to any of claims 49-59, wherein said step of separating comprises conditioning material that is fed from the pre-treatment unit in a condition section, said conditioning comprising mixing with acidic solution to lower the pH of the material.

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61. The process according to any of claims 45-60, wherein said generating biodiesel comprises feeding said fat/oil component and thermal media through alternating compartments confined by a plurality of contact plates coated with esterification/transesterification catalyst in the reaction zone and non-coated in the alternating compartments, feeding thermal media through at least some of said alternating compartments in between non-coated sides of contact plates.

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- 5 62. The process according to claim 45-61, wherein said generating biodiesel comprises first bringing said fat/oil component in contact with a catalyst that catalyzes esterification of free fatty acids and subsequently in contact with a catalyst that catalyzes transesterification of glycerides.
- 10 63. The process according to any of claims 45-60, comprising esterification of free fatty acids by homogeneous acid catalysis in a separate continuous-flow biodiesel reactor composed of a plurality of contact plates and subsequent base catalyzes transesterification of glycerides in a second continuous-flow biodiesel reactor composed of a plurality of contact plates.
- 15 64. The process according to claim 63 where water removal is achieved through flash evaporation between the reactors and/or after each reactor.
- 20 65. The process according to any of claims 45-64, where esterification and/or transesterification is promoted through the induction of turbulent flow by static mixers placed between the contact plates in the respective reaction zones.
- 25 66. The process according to any of claims 45-65, wherein said step of introducing said component comprising wet solid material into a composting unit comprises feeding said component at a temperature in the range of about 40-50°C to an initiation section of said unit to accelerate the process by subjecting the substrate directly to thermophile digestion and bypassing mesophilic stage composting.
- 30 67. The process according to claim 66, comprising addition of seed compost from the downstream compost, said feed compost being substantially at the peak of its thermophilic phase.
- 35 68. The process according to any of claims 66 to 67, comprising agitating continuously or semi-continuously and maintaining material in said initiation section for a period of time in the range of about 2-6 hours.
- 40 69. The process according to claim 66 or 68, comprising adding to the compost material carbon-rich stock to enhance the C:N ratio of the compost material.
70. The process according to claim 69, wherein said carbon-rich stock is selected from easily digestible carbon rich waste such as fruit, dough and glycerol, is the glycerol preferably from the biodiesel production of the process.
71. The process according to claim 66 or 70, comprising transferring material from said initiation section to a second stage incubation section with addition of bulking

material such as wood chips, aerating the material in said incubation section with forced aeration and humidifying the material, incubating the material in said incubation section for a period of time in the range of about 24-96 hours.

- 5 72. The process according to any of claims 66-71, further comprising transferring material from said second stage, the incubation stage, to a third stage, the aging stage, and allowing the compost material to mature in said third stage for a period of at least about three months.
- 10 73. The process according to any of claims 45-72, wherein said stream of waste comprises one or more of the waste categories: household waste, slaughterhouse waste, food industry waste, fish industry waste, waste from vegetable oil and/or fish oil industry, sewage sludge, sewage grease and oils, agricultural waste such as wheat-straw or other straw, rice husk, soybean curd residue, and grass and animal
- 15 manure, garden waste, and waste wood.
74. The process according to any of claims 45-73, further comprising a step of grinding and/or shredding and homogenising the waste, upstream of the pre-treatment step.
- 20 75. The process according to any of claims 45-74, wherein the process is energy self-sufficient, such that the process does not require external sources of energy.