CLAIMS

1. A method of handling material, such as biomass, the method comprising:

conveying recalcitrance-reduced biomass along interior portions of a screw conveyor.

2. The method of claim 1, further comprising delivering the biomass to a feed inlet of the screw conveyor.

3. The method of claim 1 or 2, further comprising discharging the biomass through an outlet of the screw conveyor.

4. The method of any one of claims 1-3, wherein the biomass has been treated by accelerated electrons to reduce its recalcitrance.

5. The method of claim 4, wherein the electrons have an energy between about 0.3 MeV and about 5 MeV.

6. The method of claim 4, wherein the electrons have an energy between about 0.5 MeV and about 3.5 MeV.

7. The method of claim 4, wherein the electrons have an energy between about 0.8 MeV and about 2 MeV.

8. The method of any one of claims 4-7, wherein prior to conveying, the biomass received a dose between about 0.5 Mrad and about 50 Mrad.

9. The method of any one of claims 4-7, wherein prior to conveying, the biomass receives a dose between about 1 Mrad and about 20 Mrad.

10. The method of any one of claims 4-7, wherein prior to conveying, the biomass receives a dose of between about 5 Mrad and about 15 Mrad.

11. The method any one of the above claims, wherein interior portions along which the biomass is conveyed, such as screw shaft, flighting and/or housing, are cooled.

12. The method of claim 11, wherein at least some of the interior portions are cooled using a chilled liquid, such as water or glycol water mixtures.

13. The method of claim 12, wherein the chilled water is chilled utilizing a cooling tower and/or geothermal cooling.

14. The method of any one of the previous claims, wherein the conveyer has a biomass inlet and a biomass discharge and wherein a difference in temperature between the biomass at the inlet and the discharge is less than about 110 °C.

15. The method of any one of the previous claims, wherein the conveyer has a biomass inlet and a biomass discharge and wherein a difference in temperature between the biomass at the inlet and the discharge is less than about 75 °C.

16. The method of any one of the previous claims, wherein the conveyer has a biomass inlet and a biomass discharge and wherein a difference in temperature between the biomass at the inlet and the discharge is less than about 50 °C.

17. The method of any one of the previous claims, wherein the conveyer has a biomass inlet and a biomass discharge and wherein a difference in temperature between the biomass at the inlet and the discharge is less than about 25 °C.

18. The method of any one of the previous claims, further comprising comminuting the biomass material while conveying the biomass material.

19. The method of claim 18, wherein comminuting comprises shredding.

20. The method of claim 18, wherein comminuting comprises shearing.

21. The method of any one of the previous claims, wherein an additive is combined with the biomass material prior to, during and/or after conveying the treated biomass material.

22. The method of claim 21, wherein the additive is selected from the group consisting of, water, an acid, a base, a metal, a resin, an inorganic material, and mixtures thereof.

23. The method of claim 22, wherein the acid is sulfuric acid, hydrochloric acid or phosphoric acid.

24. A method of processing a material, the method comprising;

providing a material to a first treatment cell equipped with a first electron beam device,

irradiating the material with electron beams using the first electron beam device, and

cooling and conveying the material with a screw conveyor from the first treatment cell.

25. The method of claim 24, further comprising conveying the material to a second treatment cell equipped with an second electron beam device and irradiating the material with an electron beam using the second electron beam device.

26. The method of claim 24 or 25, wherein the screw conveyor comprises interior portions such as screw shaft, flighting and/or housing that is cooled.

27. The method of claim 26, wherein the interior portions are cooled using a chilled liquid, such as water or glycol water mixtures.

28. The method of any one of claims 24-27, wherein the cooling reduces the temperature of the material by between about 1°C and 110 °C.

29. The method of any one of claims 24-27, wherein the cooling reduces the temperature of the material by between about 10°C and about 75 °C.

30. The method of any one of claims 24-27, wherein the cooling reduces the temperature of the material by between about 10°C and about 50 °C.

31. The method of any one of claims 24- 30, wherein a total dose delivered is between about 1 and 200 Mrad.

32. The method of any one of claims 24 -30, wherein a total dose delivered is between about 10 Mrad and about 50 Mrad.

33. The method of any one of claims 24 -30, wherein a total dose delivered is between about 20 Mrad and about 40 Mrad.

34. The method of any one of claims 24 - 33, wherein the temperature of the material during the irradiation does not exceed about 200 °C.

35. The method of any one of claims 24 through 33, wherein the temperature of the material during the irradiation does not exceed about 180 °C.

36. The method of any one of claims 24 through 33, wherein the temperature of the material during the irradiation does not exceed about 160 °C.

37. The method of any one of claims 24 through 33, wherein the temperature of the material during the irradiation does not exceed about 150 °C.

38. The method of any one of claims 24 through 33, wherein the temperature of the material during the irradiation does not exceed about 140 °C.

39. The method of any one of claims 24 through 33, wherein the temperature of the material during the irradiation does not exceed about 130 °C.

40. The method of any one of claims 24 through 33, wherein the temperature of the material during the irradiation does not exceed about 120 °C.

41. The method of any one of claims 24 through 33, wherein the temperature of the material during the irradiation does not exceed about 110 °C.

42. The method of any one of claims 24 - 41, wherein the temperature of the material during irradiation increases by between about 10 °C and about 250 °C.

43. The method of any one of claims 24 - 41, wherein the temperature of the material during irradiation increases by between about 10 °C and about 150 °C

44. The method of any one of claims 24 - 41, wherein the temperature of the material during irradiation increases by between about 50 °C and about 150 °C.

45. The method of any one of claims 24 – 41, wherein the temperature of the material during irradiation increases by between about 75 °C and about 150 °C.

46. The method of any one of claims 24 through 45, wherein the material comprises a biomass.

47. The method of claim 46, wherein the biomass comprises a lignocellulosic material.

48. The method of claim 46, wherein the biomass is selected from the group consisting of wood, particle board, sawdust, agricultural waste, sewage, silage, grasses, rice hulls, bagasse, cotton, jute, hemp, flax, bamboo, sisal, abaca, straw, corn cobs, corn stover, switchgrass, alfalfa, hay, coconut hair, seaweed, algae, and mixtures thereof.

49. The method of any one of the previous claims, wherein the screw conveyor comprises two or more screws.

CLAIMS

1. A method of processing a biomass material, the method comprising; providing a biomass material to a first treatment cell equipped with a first electron beam device, irradiating the biomass material with electron beams using the first electron beam device, and cooling and conveying the biomass material with a screw conveyor from the first treatment cell.

2. The method of claim 1, further comprising conveying the biomass material to a second treatment cell equipped with an second electron beam device and irradiating the biomass material with an electron beam using the second electron beam device.

3. The method of claim 1 or 2, wherein the screw conveyor comprises interior portions that are cooled.

4. The method of claim 3, wherein the interior portions are cooled using a chilled liquid.

5. The method of any one of claims 1-4, wherein the cooling reduces the temperature of the biomass material by between about 1°C and 110 °C.

6. The method of any one of claims 1-4, wherein the cooling reduces the temperature of the biomass material by between about 10°C and about 75 °C.

7. The method of any one of claims 1-4, wherein the cooling reduces the temperature of the biomass material by between about 10°C and about 50 °C.

8. The method of any one of claims 1-7, wherein a total dose delivered is between about 1 and 200 Mrad.

9. The method of any one of claims 1-7, wherein a total dose delivered is between about 10 Mrad and about 50 Mrad.

10. The method of any one of claims 1-7, wherein a total dose delivered is between about 20 Mrad and about 40 Mrad.

11. The method of any one of claims 1-10, wherein the temperature of the biomass material during the irradiation does not exceed about 160 °C.

12. The method of any one of claims 1-10, wherein the temperature of the biomass material during irradiation increases by between about 75 °C and about 150 °C.

13. The method of any one of claims 1-12, wherein the biomass comprises a lignocellulosic material.

14. The method of any one of claims 1-12, wherein the biomass is selected from the group consisting of wood, particle board, sawdust, agricultural waste, sewage, silage, grasses, rice hulls, bagasse, cotton, jute, hemp, flax, bamboo, sisal, abaca, straw, corn cobs, corn stover, switchgrass, alfalfa,hay, coconut hair, seaweed, algae, and mixtures thereof.

15. The method of any one of claims 1-14, wherein the screw conveyor comprises two or more screws.

16. The method of any one of claims 1-15, wherein irradiating with the first electron beam delivers a dose at a rate of at least 1 Mrad per second to the biomass material.

17. The method of any one of claims 2-16, wherein irradiating with the second electron beam device delivers a dose at a rate of at least 1 Mrad per second to the biomass material.

18. The method of any one of claims 1-17, wherein the screw conveyor has a material inlet and a material discharge, and wherein a difference in temperature of the biomass material between the material at the inlet and at the discharge is less than about 110 °C.

19. The method of any one of claims 1-18, wherein the biomass material is comminuted while it is conveyed.

20. The method of claim 4, wherein the interior portions are cooled using water or glycol water mixtures.