CLAIMS

WHAT IS CLAIMED IS:

1. A method of carbon removal comprising

(i) either

(a)providing carbon dioxide derived from a gas comprising methane and carbon dioxide generated by anaerobic digestion of organic material at a first site, wherein at least a portion of the carbon dioxide is separated from the methane to produce a carbon dioxide portion and a methane portion, or

(b) providing carbon dioxide derived from a composition generated by direct air capture of carbon dioxide at a second site by separating at least a portion of carbon dioxide from the composition; and

(ii) sequestering at least part of the carbon dioxide portion at a third site by chemically reacting it or a reaction product of it to form a carbon dioxide sequestration product or products.

2. The method of claim 1 wherein the first and second sites are different from the third site.

3. The method of claim 2 further comprising, at the first site and/or the second site, processing the carbon dioxide, if necessary, to render it suitable for transport, and transporting the carbon dioxide to the third site.

4. The method of any previous claim wherein the carbon dioxide portion of (i)(a) comprises one or more contaminants.

5. The method of claim 4 wherein the nature and/or concentration of the contaminants render it unsuitable as a food-grade carbon dioxide.

6. The method of claim 4 wherein the one or more contaminants comprise organic matter (e.g., fecal matter), one or more sulfur compounds (e.g., H2S, thiols), ammonia, siloxanes, or a combination thereof.

7. The method of claim 6 wherein the impurities are present at a combined level of at least 0.001, 0.01, 0.09, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.5, 1.7, 2, 2.5, 3, 3.5, 4, 4.5, 5, 6, 7, 8, 9, 10, 12, 15, or 20%, such as at least 0.09%.

8. The method of any of claims 4-6 and 7 wherein at least a portion of the one or more contaminants is sequestered in the carbon dioxide sequestration product or products.

9. The method of claim 1 wherein the organic material comprises landfill, waste water treatment product (e.g., sewage sludge), animal manure, food waste, agricultural residue, forestry and/or forest product residue, energy crops, municipal solid waste, or a combination thereof.

10. The method of any previous claim wherein the carbon dioxide sequestration product or products comprise a mineralized product.

11. The method of any previous claim wherein the carbon dioxide sequestration product or products comprise one or more carbonated concrete production products.

12. The method of claim 11 wherein the carbonated concrete production product comprises carbonated concrete, carbonated concrete wash water, carbonated recycled concrete aggregates, or a combination thereof.

13. A method comprising

(i) providing carbon dioxide that contains at least 0.09% contaminants;

(ii) sequestering at least part of the carbon dioxide by chemically reacting it or a reaction product of it to form a carbon dioxide sequestration product or products

14. The method of claim 13 wherein the one or more contaminants comprise one or more of organic matter (e.g., fecal matter), one or more sulfur compounds (e.g., H2S, thiols), ammonia, siloxanes, water vapor, nitrogen, oxygen, hydrogen, carbon monoxide, halogenated hydrocarbons, other volatile and semi-volatile organic compounds, heavy metals or a combination thereof.

15. The method of claim 13 or 14 wherein the one or more contaminants comprises one or more of organic matter (e.g., fecal matter), one or more sulfur compounds (e.g., H2S, thiols), ammonia, siloxanes, or a combination thereof.

16. The method of any one of claim 13-15 wherein the carbon dioxide is produced during ethanol production, biogas production, hydrogen production, direct air capture, or a combination thereof.

17. The method of any one of claim 13-16 wherein the sequestering comprises contacting the carbon dioxide with concrete or a concrete product.

18. A method comprising

(i) providing a gas comprising carbon dioxide wherein the carbon dioxide is derived, directly or indirectly, from atmospheric carbon dioxide; and

(ii) sequestering at least part of the carbon dioxide by chemically reacting it or a reaction product of it to form a carbon dioxide sequestration product or products

19. The method of claim 18 wherein the carbon dioxide comprises carbon dioxide obtained by DAC.

20. The method of claim 18 wherein the carbon dioxide comprises carbon dioxide produced by anaerobic digestion of organic material.

21. The method of claim 18 wherein the carbon dioxide comprises carbon dioxide produced during ethanol production, e.g., from a biomass crop, such as corn.

22. The method of claim 18 wherein the carbon dioxide comprises carbon dioxide produced during production of H2, e.g., production of H2 from biomass.

23. The method of claim 18 wherein the sequestering comprises contacting the carbon dioxide with concrete or a concrete product.

24. A carbon removal system comprising

(i) a carbon dioxide-producing facility comprising a source of carbon dioxide derived directly or indirectly from the atmosphere, wherein the facility comprises a system for processing the carbon dioxide to render it suitable for transport, if necessary; and

(ii) a sequestration plant to which the carbon dioxide is transported, if necessary, and which comprises one or more systems to perform one or more processes that binds the carbon dioxide or one or more carbon dioxide reaction products with one or more reactants to produce one or more carbon dioxide sequestration products.

25. The system of claim 24 wherein the source is a source of biogenic carbon dioxide.

26. The system of claim 25 wherein the carbon dioxide-producing facility comprises a biogas plant.

27. The system of claim 26 wherein the biogas plant comprises a landfill gas (LFG) biogas plant, animal manure biogas plant, water resource recovery facilities (WRRF) biogas plant, food waste biogas plant, agricultural residue biogas plant, forestry and/or forest product residue biogas plant, energy crops biogas plant, municipal solid waste (MSW) biogas plant, renewable electricity biogas plant, or a combination thereof.

28. The system of any one of claims 24-27 wherein the sequestration plant comprises a concrete manufacturing plant, a concrete product processing plant, or a combination thereof.

29. The system of claim 28 wherein the one or more systems at the concrete manufacturing plant or concrete product processing plant to process the carbon dioxide comprise a system to deliver at least a portion of the carbon dioxide to a mixing concrete mix, a system to deliver at least a portion of the carbon dioxide to a wet concrete mix, a system to deliver at least a portion of the carbon dioxide to concrete wash water, a system to deliver at least a portion of the carbon dioxide to recycled concrete aggregates, or a combination thereof, optionally wherein two or more, e.g., three, or all four systems are different systems.

30. A composition comprising concrete materials, carbon dioxide reaction products, and one or more contaminants, wherein the one or more contaminants was produced in a process for directly or indirectly removing carbon dioxide from the atmosphere.

31. A method of sequestering carbon dioxide comprising

(i) providing carbon dioxide produced in the production of hydrogen; and

(ii) binding the carbon dioxide with one or more reactants to the carbon dioxide or a carbon dioxide reaction product and the one or more reactants to produce one or more carbon dioxide sequestration products, thus sequestering the carbon dioxide.

32. A method of sequestering a composition comprising carbon dioxide and one or more impurities, wherein the one or more impurities comprise one or more of organic matter (e.g., fecal matter), one or more sulfur compounds (e.g., H_2S, thiols), ammonia, siloxanes, water vapor, nitrogen, oxygen, hydrogen, carbon monoxide, halogenated hydrocarbons, other volatile

and semi-volatile organic compounds, heavy metals or a combination thereof, in some cases one or more of organic matter (e.g., fecal matter), one or more sulfur compounds (e.g., H2S, thiols), ammonia, siloxanes, or a combination thereof, comprising reacting the composition with one or more concrete products to form one or more compositions in which the carbon dioxide and at least a portion of the one or more impurities are permanently sequestered.

33. A method of carbon removal comprising

(i) providing carbon dioxide derived from a gas comprising carbon dioxide, wherein the carbon dioxide in the gas is generated by direct or indirect capture of carbon dioxide from the atmosphere at a first site;

(ii) processing the carbon dioxide, if necessary, to render it suitable for transport;

(iii) transporting the carbon dioxide to a second site; and

(iv)sequestering at least part of the carbon dioxide portion at a secnd site by chemically reacting it or a reaction product of it to form a carbon dioxide sequestration product or products.

34. The method of claim 33 wherein the second site comprises a concrete product site and at least a portion of the carbon dioxide is sequestered by carbonation of one or more concrete products.

35. The method of claim 34 wherein chemically reacting the carbon dioxide or a reaction product of the reaction to form a carbon dioxide sequestration product or products comprises at least one of

(a) carbonation of a mixing concrete mix;

(b) carbonation of a wet concrete mix;

(c) carbonation of concrete wash water to provide a carbonated wash water; and/or

(d) carbonation of recycled concrete aggregates.

36. The method of claim 35 wherein at least a portion of the carbonated wash water is used as mix water in a batch of concrete.

37. The method of any of claims 33-36 wherein the carbon dioxide portion of (i) comprises one or more contaminants.

38. The method of claim 37 wherein the nature and/or concentration of the contaminants render it unsuitable as a food-grade carbon dioxide.

39. The method of claim 38 wherein the one or more contaminants comprise organic matter (e.g., fecal matter), one or more sulfur compounds (e.g., H2S, thiols), ammonia, siloxanes, or a combination thereof.

40. The method of claim 39 wherein the carbon dioxide comprises 0.01-10% contaminants (w/w).

41. The method of any of claims 33-40 wherein the first site comprises a biogas plant, an ethanol production plant, a direct air capture plant, a hydrogen production plant, or a combination thereof.

42. The method of claim 41 wherein the first site comprises a biogas plant.

43. The method of claim 42 wherein the biogas plant comprises wherein the biogas plant comprises a landfill gas (LFG) biogas plant, animal manure biogas plant, water resource recovery facilities (WRRF) biogas plant, food waste biogas plant, agricultural residue biogas plant, forestry and/or forest product residue biogas plant, energy crops biogas plant, municipal solid waste (MSW) biogas plant, renewable electricity biogas plant, or a combination thereof.

44. A method comprising

(i) providing carbon dioxide derived from a gas comprising carbon dioxide and methane, wherein the gas is generated at a first biogas site;

(ii) processing the carbon dioxide, if necessary, to render it suitable for transport;

(iii) transporting at least a portion of the carbon dioxide to a first sequestration site; and

(iv) sequestering at least part of the carbon dioxide portion at the first sequestration site by chemically reacting it or a reaction product of it to form a carbon dioxide sequestration product or products.

45. The method of claim 44 wherein the second site comprises a concrete product site and at least a portion of the carbon dioxide is sequestered by carbonation of one or more concrete products.

46. The method of claim 45 wherein chemically reacting the carbon dioxide or a reaction product of the carbon dioxide to form a carbon dioxide sequestration product or products comprises at least one of

(a) carbonation of a mixing concrete mix;

(b) carbonation of a wet concrete mix;

(c) carbonation of concrete wash water to provide a carbonated wash water; and/or

(d) carbonation of recycled concrete aggregates.

47. The method of any of claims 44-46 wherein the carbon dioxide portion derived from a gas comprising carbon dioxide and methane comprises one or more contaminants.

48. The method of claim 47 wherein the one or more contaminants comprise organic matter (e.g., fecal matter), one or more sulfur compounds (e.g., H2S, thiols), ammonia, siloxanes, or a combination thereof.

49. The method of claims 47 or 48 wherein the carbon dioxide comprises 0.01-10% contaminants (w/w).

50. The method of any of claims 44-49 wherein at least a portion of the one or more contaminants is sequestered in the carbon dioxide sequestration product or products.

51. The method of any of claims 44-50 wherein the first biogas plant, and/or second, third, fourth biogas plants, if present, comprise a landfill gas (LFG) biogas plant, animal manure biogas plant, water resource recovery facilities (WRRF) biogas plant, food waste biogas plant, agricultural residue biogas plant, forestry and/or forest product residue biogas plant, energy crops biogas plant, municipal solid waste (MSW) biogas plant, renewable electricity biogas plant, or a combination thereof.

52. The method of any of claims 44-51 wherein the first concrete product site, and/or second, third, fourth concrete product site, comprises a concrete manufacturing plant, a concrete product processing plant, or a combination thereof.