What is claimed:

1. A system for recovering syngas from a methane feedstock, comprising:

a first stage comprising a photocatalytic steam methane reformer, the first stage configured to produce at least a carbon dioxide stream and a hydrogen stream from the methane feedstock, and to contact the methane feedstock with steam in the presence of a first plasmonic photocatalyst; and

a second stage, adjacent to and downstream from the first stage, comprising a photocatalytic dry methane reformer configured to produce the syngas from a second methane feedstock and the carbon dioxide stream produced in the first stage.

2. The system of claim 1, wherein the first stage is

configured to contact the methane feedstock with steam in the presence of the first plasmonic photocatalyst to form a first reaction product stream comprising hydrogen and carbon monoxide; and

wherein the first stage further comprises a water-gas shift reactor configured for contacting the first reaction product stream with water to form a water-gas shift stream comprising hydrogen and carbon dioxide.

3. The system of claim 2, wherein the first stage further comprises:

a separation unit configured to separate carbon dioxide from the water-gas shift stream to obtain the carbon dioxide stream and the hydrogen stream.

4. The system of claim 2 or 3, wherein the photocatalytic steam methane reformer comprises:

a housing;

at least one reactor cell disposed within an interior of the housing, the at least one reactor cell comprising an enclosure and the first plasmonic photocatalyst on a first catalyst support disposed within the at least one enclosure, wherein the enclosure is optically transparent and comprises at least one input configured for the methane feedstock to enter the at least one cell and at least one output for the first reaction product stream to exit the at least one cell; and

at least one light source, wherein, the reactor cell is configured to form the first reaction product stream from the methane feedstock upon application of the at least one light source.

5. The system of any of claims 2 to 4, wherein the first plasmonic photocatalyst comprises a first catalyst coupled to a plasmonic material.

6. The system of claim 5, wherein the first catalyst comprises catalytically active iron, nickel, cobalt, platinum, palladium, rhodium, or ruthenium, and wherein the plasmonic material is aluminum, copper, silver, or gold.

7. The system of any of claims 1 to 6, wherein the first stage is configured to utilize an organic Rankine cycle to generate electricity within the system using process waste heat.

8. The system of any of claims 1 to 7, wherein the photocatalytic dry methane reformer comprises:

a housing;

at least one reactor cell disposed within an interior of the housing, the at least one reactor cell comprising an enclosure and a second plasmonic photocatalyst on a second catalyst support disposed within the at least one enclosure, wherein the enclosure is optically transparent and comprises one or more inputs configured for the second methane feedstock and the carbon dioxide stream to enter the at least one cell and at least one output for the syngas to exit the at least one cell; and

at least one light source, wherein, the reactor cell is configured to form the syngas from the second methane feedstock and the carbon dioxide stream upon application of the at least one light source.

9. The system of claim 8, wherein the second plasmonic photocatalyst comprises a second catalyst coupled to a plasmonic material.

10. The system of claim 9, wherein the second catalyst comprises catalytically active iron, nickel, cobalt, platinum, rhodium, or ruthenium, and wherein the plasmonic material is aluminum, copper, silver or gold.

11. The system of any of claims 1 to 10, further comprising a third stage, adjacent to and downstream from the second stage, comprising a synthesis reactor configured to produce methanol or dimethyl ether from the syngas produced in the second stage.

12. The system of claim 11, wherein a hydrogen stream is provided to the synthesis reactor in the third stage so that the molar ratio of carbon monoxide and hydrogen in the synthesis reactor is 1 : 2.

13. The system of claim 11, wherein the hydrogen stream is obtained in the first stage.

14. The system of claim 11, wherein the second stage comprises a shift reactor, adjacent to and downstream from the photocatalytic dry methane reformer, the shift reactor configured to produce the hydrogen stream, wherein the hydrogen stream obtained in the second stage is provided to the synthesis reactor in the third stage so that the molar ratio of carbon monoxide and hydrogen in the synthesis reactor is1 : 2.

15. The system of claim 11, wherein the second stage comprises a hydrogen separation membrane, adjacent to and downstream from the photocatalytic dry methane reformer, and the hydrogen separation membrane configured to produce the hydrogen stream, wherein the hydrogen stream obtained in the second stage is provided to the synthesis reactor in the third stage so that the molar ratio of carbon monoxide and hydrogen in the synthesis reactor is1 : 2.

16. A method for transforming a methane feedstock into syngas, comprising

providing the methane feedstock to a first stage comprising a photocatalytic steam methane reformer to obtain at least a carbon dioxide stream and a hydrogen stream,

contacting the methane feedstock with steam in the presence of a first plasmonic photocatalyst within the photocatalytic steam methane reformer; and

providing the carbon dioxide stream to a second stage comprising a photocatalytic dry methane reformer to produce the syngas.

17. The method of claim 16, wherein, in the first stage, the methane feedstock is provided to the photocatalytic steam methane reformer to form a first reaction product stream comprising hydrogen and carbon monoxide, followed by providing the first reaction product stream and water to a water-gas shift reactor to form a water-gas shift stream comprising hydrogen and carbon dioxide.

18. The method of claim 17, the method further comprising:

in the photocatalytic steam methane reformer, distributing the methane feedstock into a plurality of reactor cells disposed within a photocatalytic steam methane reformer housing, wherein each reactor cell comprises an optically transparent enclosure and the first plasmonic photocatalyst on a first catalyst support disposed within the optically transparent enclosure;

illuminating, via at least one light source, the first plasmonic photocatalyst on the first catalyst support of each of the plurality of reactor cells to cause the plurality of reactor cells to transform the methane feedstock into the first reaction product stream comprising hydrogen and carbon monoxide; and

accumulating the first reaction product stream from the plurality of reactor cells.

19. The method of claim 17 or 18, further comprising providing the water-gas shift stream comprising hydrogen and carbon dioxide to a separation unit to obtain the carbon dioxide stream and the hydrogen stream.

20. The method of any of claims 16 to 19, further comprising:

in the photocatalytic dry methane reformer, distributing the carbon dioxide stream and a second methane feedstock into a plurality of reactor cells disposed within a photocatalytic dry methane reformer housing, wherein each reactor cell comprises an optically transparent enclosure and a second plasmonic photocatalyst on a second catalyst support disposed within the optically transparent enclosure;

illuminating, via at least one light source, the second plasmonic photocatalyst on the second catalyst support of each of the plurality of reactor cells to cause the plurality of reactor cells to transform the carbon dioxide and methane into the syngas; and

accumulating the syngas from the plurality of reactor cells.

21. A method for preparing methanol or dimethyl ether from a methane feedstock, comprising:

providing the methane feedstock to a first stage comprising a photocatalytic steam methane reformer to obtain at least a carbon dioxide stream and a hydrogen stream;

providing the carbon dioxide stream to a second stage comprising a photocatalytic dry methane reformer to produce a syngas; and

providing the syngas and the hydrogen stream to a third stage comprising a synthesis reactor to obtain methanol or dimethyl ether.

22. The method of claim 21, wherein the hydrogen stream is provided to the synthesis rector in the third stage so that the molar ratio of carbon monoxide and hydrogen in the reactor is 1 : 2.