Apparatuses and methods for dismantling photovoltaic modules

Technical Field

[0001] This disclosure generally relates to the dismantling of photovoltaic modules.

Background

[0002] This background description is provided for the purpose of generally presenting the context of the disclosure. Contents of this background section are neither expressly nor impliedly admitted as prior art against the present disclosure.

[0003] Photovoltaic (PV) modules form part of solar energy harvesting systems or solar farms. Solar farms comprise a large collection of photovoltaic (PV) solar panels that absorb energy from the sun, convert it into electricity and transmit that electricity to the power grid for distribution and consumption. A PV module comprises several interconnected solar cells. The solar cells are encapsulated between a sun-facing glass layer and a back sheet or another glass layer. The former is known as glass-back sheet PV module, while the latter is known as glass-glass PV module. The glass layer protects the solar cells and ensures the robustness of the entire PV module while maintaining a high degree of transparency. The back sheet is often made from a plastic material that electrically isolates, protects and shields the PV cells from weather and moisture. The back sheet, solar cell and glass layer are bound together using layers of encapsulating material. The entire PV module is secured at its periphery using a frame that is often fabricated using aluminium or an aluminium alloy. The frame ensures robustness and a practical and safe coupling to the PV module. A layer of sealant may be deposited around the parts of the PV module contacting the frame as a moisture barrier. A junction box is provided for housing the electrical connections of the PV module. The junction box is often provided on a side of the PV module opposite of the side intended to be directed towards the sun.

[0004] PV modules are provided outdoors and are continuously subjected to harsh weather conditions. Over time PV modules degrade and require replacement. Particularly when provided in remote solar farms, the process of dismantling PV modules presents a significant technical and logistical challenge. PV modules comprise valuable components

that may be recycled after effective dismantling. There is a need to provide more efficient apparatuses and methods for dismantling PV modules or at least provide a useful alternative to any existing apparatuses and methods.

Summary

[0005] Some embodiments relate to an apparatus for dismantling photovoltaic (PV) modules, the apparatus comprising:

a frame removal station;

a PV module dismantling station;

a solar cell separation station; and

one or more conveyor elements configured to convey the PV modules through the stations;

wherein the apparatus is configured to:

receive a PV module on one end of one of the conveyor elements;

separate a frame from the PV module by the frame removal station to recover the frame and obtain a frameless PV module;

separate a junction box and a back sheet from the frameless PV module by the PV module dismantling station to recover the junction box and the back sheet and obtain a partially disassembled PV module; and

separate encapsulated solar cells from the partially disassembled PV module by the solar cell separation station to recover a glass panel and obtain encapsulated solar cells;

wherein the apparatus is mountable on a vehicle for on-site dismantling operations.

[0006] In some embodiments, the frame removal station comprises a tool positioning system with a frame removal tool mounted on an end of the tool positioning system to separate the frame from the PV module.

[0007] In some embodiments, the frame removal tool comprises a retractable holding jig to secure at least a part of the frame and apply pressure outwards onto the part of the frame for removal.

[0008] In some embodiments, the PV module is rectangular with a frame element attached on each side of the rectangular PV module; and the frame removal tool comprises a plurality of holding jigs, each jig being positioned to secure and apply pressure outwards onto the frame element.

[0009] In some embodiments, the PV module dismantling station comprises a tool positioning system equipped with at least one of: a scraper, a cutting tool or a picking tool, wherein the scraper is provided at one end and configured to separate the junction box from the frameless PV module; the cutting tool is configured to cut the back sheet after the separation of the junction box by the scraper; and the picking tool is provided at another end and configured to pick up and peel off the back sheet after the back sheet is cut by the cutting tool.

[0010] In some embodiments, the solar cell separation station comprises a tool positioning system with a scraping tool mounted on one end of the tool positioning system to scrape off the encapsulated solar cells from the partially disassembled PV module.

[0011] In some embodiments, the scraping tool comprises one or more alignment tools to control the depth at which scraping is performed by the scraping tool.

[0012] In some embodiments, the frame removal station comprises one or more holding elements to collect separated frames.

[0013] In some embodiments, the tool positioning system is a 3-axis motion system or a robotic arm system.

[0014] Some embodiments relate to a method of dismantling photovoltaic (PV) modules using the apparatus as disclosed herein, the method comprising:

providing a PV module on one end of the conveyor elements;

separating a frame from the PV module by the frame removal station to recover the frame and obtain a frameless PV module;

separating a junction box and a back sheet from the frameless PV module by the PV module dismantling station to recover the junction box and the back sheet and obtain a partially disassembled PV module; and

separating encapsulated solar cells from the partially disassembled PV module by the solar cell separation station to recover a glass panel and obtain encapsulated solar cells.

[0015] Some embodiments relate to a vehicle comprising the apparatus as disclosed herein, the apparatus being provided in the vehicle's hold; wherein the vehicle is configured to receive PV modules on one end of the one or more conveyor elements of the apparatus through an opening in its hold to dismantle the PV modules.

[0016] Some embodiments relate to a method for on-site dismantling of PV modules, the method comprising:

providing the vehicle as disclosed herein;

providing PV modules on one end of the one or more conveyor elements of the apparatus;

dismantling of the PV modules by operation of the apparatus; and

recovery of dismantled components of the PV modules.

Brief Description of the Drawings

[0017] Some embodiments of apparatuses and methods for dismantling PV modules, in accordance with the present disclosure, will now be described, by way of non-limiting example only, with reference to the accompanying drawings in which:

[0018] Figure 1 illustrates a flowchart of a method of dismantling a PV module;

[0019] Figure 2 illustrates a vehicle comprising a containerized apparatus for dismantling PV modules;

[0020] Figure 3 illustrates a cross-section view of various stations of an apparatus for dismantling PV modules during transportation;

[0021] Figure 4 illustrates a cross-section view of various stations of an apparatus for dismantling PV modules during operation;

[0022] Figures 5 to 8 illustrate parts of a frame removal station of an apparatus;

[0023] Figure 9 illustrates a perspective view of a series of stations of the apparatus;

[0024] Figure 10 illustrates a perspective view showing some internal parts of a series of stations of the apparatus;

[0025] Figure 11 illustrates a side view of a series of stations of the apparatus;

[0026] Figure 12 illustrates a top view of a series of stations of the apparatus;

[0027] Figure 13 illustrates an inside view of a frame removal station of the apparatus;

[0028] Figure 14 illustrates an inside view of a PV module dismantling station; and

[0029] Figure 15 illustrates an inside view of a solar cell separation station of the apparatus.

Detailed Description

[0030] Disclosed embodiments relate to an apparatus (900 of Figures 9, 10, 11 and 12) for dismantling PV modules and a method (Figure 1) for dismantling PV modules using the apparatus, wherein the PV modules may be glass-back sheet PV modules. Some embodiments also relate to a vehicle (10 of Figure 2) comprising the apparatus for dismantling PV modules and method for the on-site dismantling of PV modules using the vehicle. The apparatus for dismantling PV modules comprises a series of stations for performing specific dismantling actions. The stations include a frame removal station (21 of Figure 3 and 31 of Figure 4), a PV module dismantling station (22 of Figure 3 and 32 of Figure 4) and a solar cell separation station (23 of Figure 3 and 33 of Figure 4). A conveyor element (305, 315, 325 and 335 of Figure 4) is provided to convey PV modules through the stations. Based on Figure 1, the apparatus is configured to receive a PV module on one end of the conveyor element (step 1, 110), separate a frame from the PV module by the frame removal station to recover a frame (122) and obtain a frameless PV module (step 2, 120), separate a junction box and a back sheet from the frameless PV module to recover the junction box and the back sheet (132) and obtain a partially disassembled PV module by the PV module dismantling station (step 3, 130), and separate encapsulated solar cells (EVA-Si solar cells) from the partially disassembled PV module to obtain EVA-Si solar cells and recover a glass panel (142) from the partially disassembled PV module by the solar cell separation station (step 4, 140). Advantageously, the apparatus is containerized and mountable on a vehicle, thus enabling it to be mobile and operable close to a solar farm allowing the dismantling of the PV modules on-site. The on-site dismantling of PV modules allows the recovery of useful

materials from the PV modules. Transport of whole PV modules is more logistically challenging and expensive due to higher transportation volume and weight. Hence, further advantageously, the on-site dismantling of the PV modules using the embodiments makes the transport and recycling of PV modules less complex and less expensive with substantive volume and weight reduction. The embodiments also improve the degree to which materials are recovered from PV modules in comparison to conventional recycling techniques.

[0031] The methods of some embodiments are configured to dismantle PV modules with a rear-glass back sheet. In such embodiments, at step 3 (130 of Figure 1), to separate the rear-glass back sheet and access the encapsulated solar cell, the rear-glass back sheet is grinded by a grinding tool in the PV module dismantling station to obtain glass shards that may be collected and thereby provide access to the encapsulated solar cells for subsequent dismantling and recovery.

Frame Removal Station

[0032] Based on Figure 3, the frame removal station (21) comprises a container/housing (211) for housing the components of the station. Frame removal station 21 comprises two operation windows (212) for allowing the entry and exit of PV modules, a frame removal tool (2131) and a horizontal working bed with a conveyor element (214). The frame removal station (21) comprises a tool positioning system (213) with the frame removal tool (2131) mounted on an end of the tool positioning system to separate the frame from the PV module. Based on Figure 8, the frame removal tool may comprise a retractable holding jig (812) to secure at least a part of the frame (810) and apply pressure outwards onto the part of the frame for removal. The arrow (816) indicates the direction in which force is applied by the retractable holding jig with respect to the PV module (814). In some embodiments, the PV module (814) is rectangular with a frame element provided on each side of the rectangular PV module. The frame removal tool may comprise a plurality of holding jigs, each jig is positioned to secure and apply pressure directed towards each frame element. The frame removal station also comprises one or more holding elements to collect separated frames. The holding element may be in the form of a rack or a collection container provided to collect the frames as they are separated from the PV module.

[0033] The frame removal station of some embodiments comprise one or more hydraulic presses to hold down or secure the PV module while the frames are removed.

The hydraulic presses may be provided in a roof region of the frame removal station. By securing the PV module during frame dismantling, the hydraulic presses reduce the likelihood of movement of the PV module which may result in incomplete removal of frames, thereby improving the efficiency of the apparatuses.

[0034] In some embodiments, holding arms and guards may be provided on a periphery of the frame removal station to enhance collection of dismantled frames. The collected frames may be deposited on a material recovery conveyer belt (1250 of Figure 12, for example) for subsequent recovery and transport.

PV Module Dismantling Station

[0035] The PV module dismantling station separates the junction box and back sheet from the frameless PV module after the separation of the frame. Separation of the frame allows the recovery of the back sheet. Based on Figure 3, the PV module dismantling station (22) comprises a container/housing (221) holding its various components. The container (221) comprises two operational windows (222) to allow entry and exit of the frameless PV modules from the frame removal station (21). A tool positioning system (223) is provided with a scraper (2231), a cutting tool (2232) (for example a wheel cutter) and a pick-up tool (2233). Also provided in the dismantling station (22) is a working bed (224). The working bed (224) comprises an embedded heating element, a suction setup and a conveyor element. The scraper (2231) is configured to separate the junction box from the frameless PV module. Thereafter, the cutting tool (2232) is configured to cut the back sheet into strips that are more easily removed from the frameless PV module. After the back sheet is cut, the pick-up tool (2233) is configured to separate the back sheet from the rest of the frameless PV module. After picking up, the cut-out back sheet is deposited at a collection station or on a separate conveyor element intended for the collection of recovered materials.

[0036] The apparatus of some embodiments are configured to dismantle PV modules with a rear-glass back sheet. In such embodiments, pick-up tool (2233) is replaced with or augmented with a grinding tool. The grinding tool grinds the rear-glass back sheet into glass shards to allow access to the encapsulated solar cells for further dismantling. The glass shards may be collected using a collection conveyer for subsequent recycling.

Solar Cell Separation Station

[0037] Based on Figure 3, the solar cell separation station (23) comprises a container/housing (231), two operation windows (232) to allow entry and exit of the partially dismantled PV modules from the PV module dismantling station (22), and a tool positioning system (233) having a scraping tool. The scraping tool may be equipped with one or more alignment tools (2331) (for example alignment wheel tools). The solar cell separation station (23) also comprises a working bed (234) having an embedded heating element, a suction setup and a conveyor element. The scraping tool is configured to scrape off the encapsulated solar cells from the glass panel of the partially dismantled PV modules. The one or more alignment tools (2331) is configured to control the depth at which scraping is performed by the scraping tool, to advantageously allow the apparatuses to be flexibly used to scrape encapsulated solar cells of varying thickness. In embodiments wherein the tool positioning system is implemented using a tool positioning system (including, for example, a 3-axis motion system or a robotic arm system), motion of the scraping tool along a single axis (such as Z-axis) may be used to control the depth (i.e. depth in relation to the PV module) at which scraping is performed by the scraping tool. The ability to control the depth of scraping advantageously allows the apparatuses to be flexibly used for PV modules of varying glass thickness.

[0038] The disclosed apparatus is sufficiently well contained and modular to be loaded in a vehicle such as a truck, and can be deployed in solar farms for on-site dismantling operations. The various stations of the apparatus may be placed inside a truck to be powered by an energy generation device such as a fuel-powered generator provided within or in the proximity of the truck. Figure 2 illustrates a vehicle (10) to transport the apparatus. The vehicle (10) comprises a holder or a container (11) to house the apparatus, as well as supporting components required to drive or power the apparatus including a compressor and a vacuum machine (15). Other components of the vehicle (10) include an operational window or opening (12) provided to link up stations and transport PV modules between stations, a dismantling tool set (13), and a working bed with conveyor elements (14).

[0039] Figure 11 illustrates a side view of a series of stations of the apparatus. In frame removal station (31), there is provided a frame removal tool (1110), an adjustable conveyer belt (1120) and a horizontal working bed (1130). As illustrated by the shaded lines, parts of the conveyer belt (1120) may be varied in height, or alternatively folded to be retained within the container of the frame removal station for convenient transportation. In the PV module dismantling station (32), this is provided a pickup tool (1170), a wheel

cutter (1172), a scraper (1174) all of which are mounted on a tool positioning system (1175). The tool positioning system (1175) in this instance is a 3-axis motion system or a robotic arm system. The PV module dismantling occurs on a horizontal working bed (1178). In some embodiments, the horizontal working bed (1178) is equipped with an embedded heating element used to heat up the PV modules and loosen any gluing or adhesives in the PV module in preparation for dismantling. In the solar cell separation station (33), there is provided a scraping tool (1180) equipped with an alignment tool. The scraping tool (1180) is mounted in a tool positioning system (1182). The solar cell separation station (33) also comprises a horizontal working bed (1150) with embedded heating elements.

[0040] Figure 12 illustrates a top view of a series of stations of the apparatus. In the frame removal station (31), there is provided a hydraulic pump (1210). The hydraulic pump (1210) is used as a securing mechanism for the PV modules before frames are removed. After frames are removed, the hydraulic pump (1210) is released to allow subsequent movement of the frameless PV module. There are also illustrated materials recovery conveyer belts (1240 and 1250) for collecting recovered materials such as the frames. The PV module dismantling station (32) is equipped with a compressor (1220) to power the various elements of the station. Similarly, the solar cell separation station (33) is equipped with a vacuum (1230) to power the various components of the station that rely on vacuum pressure.

[0041] Figure 13 illustrates an inside view of a frame removal station of the apparatus. Illustrated in Figure 13 is an adjustable frame removal tool (1310) mounted on a tool positioning system (1312). The tool positioning system (1312) may be implemented using a 3-axis motion system or a robotic arm system. The PV modules may be received on the conveyer element (1330 for frame removal). Figure 14 illustrates an inside view of a PV module dismantling station (32). Illustrated in Figure 14 is a dismantling tool (1410) mounted on a 3-axis motion system (1420). Any recovered materials after the dismantling process are conveyed using the conveyer element (1430). The components of the PV module dismantling station are powered by a compressor (1440). Figure 15 illustrates an inside view of a solar cell separation station (33) of the apparatus. Illustrated in Figure 15 is a scraper (1510) with an adjustable slit mounted on a tool positioning system (1520). The tool positioning system (1520) may be implemented using a 3-axis motion system or a robotic arm system. Any recovered materials are collected using the materials recovery

conveyer belt (1530). Some components of the solar cell separation station (33) may be powered using the vacuum (1540).

[0042] The scraper (1510) of some embodiments comprises an alignment tool and a scraping end. The alignment tool may be an alignment roller. The alignment roller is used to determine a height of the encapsulated solar cells with respect to the glass panel. In operation, the alignment tool/roller may be lowered down towards the encapsulated solar cells to align and guide the operation of the scraping end. Operation of the scraping end is adjusted to perform scraping at a controlled depth lower than the alignment roller to scrap encapsulated solar cells off the glass panel. The ability to control the depth of scraper advantageously allows the apparatus to be flexibly used for encapsulated solar cells of varying thickness without the need of any specific modification.

Method of Dismantling PV Module

[0043] Some embodiments of the disclosure are directed to the method of dismantling photovoltaic (PV) modules using the disclosed apparatus. Based on Figure 1, the method comprises providing a PV module on one end of the conveyor element (step 110). After the vehicle is deployed in a solar farm, the apparatus within the vehicle is configured to dismantle PV modules. The PV modules may be placed on a segment of the conveyor element of the apparatus for sequential dismantling by the various stations of the apparatus. The various stations of the apparatus dismantle the PV module sequentially. When the PV module is received by the frame removal station, the method proceeds with separating a frame from the PV module by the frame removal station to recover a frame and obtain a frameless PV module (step 120). This is followed by separating a junction box and a back sheet from the frameless PV module to recover the junction box and the back sheet and obtain a partially disassembled PV module by the PV module dismantling station (step 130). Subsequently, encapsulated solar cells are separated from the partially disassembled PV module to obtain encapsulated solar cells and recover a glass panel from the partially disassembled PV module by the solar cell separation station (step 140).

[0044] Figure 4 illustrates an apparatus configured for dismantling PV modules during operation. A PV module (41) is loaded into the frame removing station (31) via a conveyor element (305). The tool positioning system (313) is lowered towards the PV module (41) to dismantle and recover the frame using the removing tool (3131). The PV module without frame (42) is conveyed to the PV module dismantling station (32) via a conveyor element (315). The tool positioning system (323) is lowered towards the PV module

without frame (42) to dismantle and recover the junction box by using the scraper (3231). Subsequently, the tool positioning system (323) is lowered and the back sheet of the PV module without frame (42) is cut into strips using the wheel cutter (3232). The tool positioning system (323) is lowered to peel off and recover the back sheet by using the pick-up tool (3233).

[0045] The partially disassembled PV module (43) that is without the frame, junction box and the back sheet is transferred to the solar cell separation station (33) via a conveyor element (325). The tool positioning system (333) is lowered towards the partially disassembled PV module (43) to scrape and recover a glass panel and encapsulated solar cells by using a scraper equipped with alignment wheel tool (3331). The alignment wheel tool of the solar cell separation station (33) is used to control the scraping depth based on the thickness of the encapsulated solar cells. The encapsulated solar cells are unloaded via a conveyor element (335) which allows the transfer of the encapsulated solar cells to a transportation truck. The encapsulated solar cells may be packed and transported to a centralized recycling plant for further processing.

[0046] The tool positioning systems of the various stations perform the function of positioning and moving relevant tools or tool components with respect to the PV module to perform the relevant steps of dismantling and/or recovery of materials. In some embodiments, the tool positioning system may be implemented using a 3-axis motion system integrated in each of the stations. A 3-axis motion system may comprise multiple linear axes operating in unison to provide 3-axis movement of a tool element mounted on a part of the 3-axis system. In some embodiments, the tool positioning system may be implemented using a robotic arm system.

[0047] The position of the dismantling tool in each station and the conveyor elements may be swapped or alternated according to the needs of the dismantling process. The dismantling tool for the disclosed stations may be installed on horizontal beds, while an overhead crane may be installed on the ceiling of the containerized stations for transporting PV modules between stations. In some embodiments, the disclosed stations may be containerized in a single container with a series of conveyor systems.

[0048] Embodiments according to the disclosure advantageously enable the dismantling of PV Modules on-site allowing the efficient transportation of the dismantled components. The various dismantled components may be retained on the solar farm for

use with reconstituted solar cells. Alternatively, the various dismantled components may be transported separately to their respective recycling destinations.

[0049] The various stations of the apparatus may be separated from each other and deployed independently to perform a subset of the steps of dismantling as illustrated in Figure 1. The modularity of the various stations also allows the deployment of a subset of the stations in environments where only a subset of stations needs to be deployed. For example, in some embodiments, the apparatus may comprise only the frame removal station and/or the PV module dismantling station. The modularity of the stations also allows convenient transport of the containerized modules for deployment in remote and space constrained environments. In some embodiments, each station may be containerised in standard containers of dimensions: 20 ft (2.4m×2.4m×5.9m) or 40 ft (2.4m×2.4m×12m). Advantageously, the dimensions of the various stations are may be adjusted to suit solar panels for different sizes or configurations. For example, the position of the holding jigs of the frame removal station may be varied to adapt the station to solar panels of different sizes. The frame removal station of some embodiments may allow a manual adjustment of the position of the holding jigs to adapt the frame removal station to solar panels of different dimensions.

[0050] The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavor to which this specification relates.

[0051] Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

[0052] The scope of this disclosure encompasses all changes, substitutions, variations, alterations, and modifications to the example embodiments described or illustrated herein that a person having ordinary skill in the art would comprehend. The scope of this disclosure is not limited to the example embodiments described or illustrated herein. Moreover, although this disclosure describes and illustrates respective embodiments herein as including particular components, elements, feature, functions,

operations, or steps, any of these embodiments may include any combination or permutation of any of the components, elements, features, functions, operations, or steps described or illustrated anywhere herein that a person having ordinary skill in the art would comprehend. Although this disclosure describes or illustrates particular embodiments as providing particular advantages, particular embodiments may provide none, some, or all of these advantages.

Claims

1. An apparatus for dismantling photovoltaic (PV) modules, the apparatus comprising:

   a frame removal station;

   a PV module dismantling station;

   a solar cell separation station; and

   one or more conveyor elements configured to convey the PV modules through the stations;

   wherein the apparatus is configured to:

   receive a PV module on one end of one of the conveyor elements;

   separate a frame from the PV module by the frame removal station to recover the frame and obtain a frameless PV module;

   separate a junction box and a back sheet from the frameless PV module by the PV module dismantling station to recover the junction box and the back sheet and obtain a partially disassembled PV module; and

   separate encapsulated solar cells from the partially disassembled PV module by the solar cell separation station to recover a glass panel and obtain encapsulated solar cells;

   wherein the apparatus is mountable on a vehicle for on-site dismantling operations.

2. The apparatus of claim 1, wherein the frame removal station comprises a tool positioning system with a frame removal tool mounted on an end of the tool positioning system to separate the frame from the PV module.

3. The apparatus of claim 2, wherein the frame removal tool comprises a retractable holding jig to secure at least a part of the frame and apply pressure outwards onto the part of the frame for removal.

4. The apparatus of any one of claims 1 to 3, wherein the PV module is rectangular with a frame element attached on each side of the rectangular PV module; and

the frame removal tool comprises a plurality of holding jigs, each jig being positioned to secure and apply pressure outwards onto the frame element.

5. The apparatus of any one of claims 1 to 4, wherein the PV module dismantling station comprises a tool positioning system equipped with at least one of: a scraper, a cutting tool or a picking tool,

wherein the scraper is provided at one end and configured to separate the junction box from the frameless PV module;

the cutting tool is configured to cut the back sheet after the separation of the junction box by the scraper; and

the picking tool is provided at another end and configured to pick up and peel off the back sheet after the back sheet is cut by the cutting tool.

6. The apparatus of any one of claims 1 to 5, wherein the solar cell separation station comprises a tool positioning system with a scraping tool mounted on one end of the tool positioning system to scrape off the encapsulated solar cells from the partially disassembled PV module.

7. The apparatus of claim 6, wherein the scraping tool comprises one or more alignment tools to control the depth at which scraping is performed by the scraping tool.

8. The apparatus of any one of claims 1 to 7, wherein the frame removal station comprises one or more holding elements to collect separated frames.

9. The apparatus of any one of claim 2 or claim 5 or claim 6, wherein the tool positioning system is a 3-axis motion system or a robotic arm system.

10. A method of dismantling photovoltaic (PV) modules using the apparatus of any one of claims 1 to 9, the method comprising:

providing a PV module on one end of the conveyor elements;

separating a frame from the PV module by the frame removal station to recover the frame and obtain a frameless PV module;

separating a junction box and a back sheet from the frameless PV module by the PV module dismantling station to recover the junction box and the back sheet and obtain a partially disassembled PV module; and

separating encapsulated solar cells from the partially disassembled PV module by the solar cell separation station to recover a glass panel and obtain encapsulated solar cells.

11. A vehicle comprising the apparatus of any one of claims 1 to 9 in its hold; wherein the vehicle is configured to receive PV modules on one end of the one or more conveyor elements of the apparatus through an opening in its hold to dismantle the PV modules.

12. A method for on-site dismantling of PV modules, the method comprising:

providing the vehicle of claim 11;

providing PV modules on one end of the one or more conveyor elements of the apparatus;

dismantling of the PV modules by operation of the apparatus; and

recovery of dismantled components of the PV modules.