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Refuse vehicle with range extension

Abstract

A range extension system for a refuse vehicle includes a battery, and a controller. The battery is configured to provide electrical energy for accessories of the refuse vehicle. The controller is configured to obtain a state of charge of the battery and limit operation of at least one of the accessories in response to the state of charge of the battery to extend a transportation range of the refuse vehicle.

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Background/Summary

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS (1) This application is a continuation of U.S. application Ser. No. 17/483,386, filed Sep. 23, 2021, which is a continuation-in-part of U.S. application Ser. No. 17/221,255, filed Apr. 2, 2021, which is a continuation of U.S. application Ser. No. 17/007,605, filed Aug. 31, 2020, which is a continuation of U.S. application Ser. No. 16/943,295, filed Jul. 30, 2020, which claims the benefit of and priority to U.S. Provisional Patent Application No. 62/881,089, filed Jul. 31, 2019, all of which are incorporated herein by reference in their entireties.

BACKGROUND
(1) Refuse vehicles collect a wide variety of waste, trash, and other material from residences and businesses. Operators of the refuse vehicles transport the material from various waste receptacles

within a municipality to a storage or processing facility (e.g., a landfill, an incineration facility, a recycling facility, etc.).

SUMMARY

(2) One embodiment of the present disclosure relates to a refuse vehicle. The refuse vehicle includes tractive elements, a prime mover, accessories, and a range extension system. The prime mover is configured to generate mechanical energy to drive one or more of the tractive elements. The accessories are configured to consume electrical energy to perform functions. The range extension system includes a battery, and a controller. The battery is configured to provide electrical energy for the accessories. The controller is configured to obtain a state of charge of the battery, and limit operation of at least one of the accessories in response to the state of charge of the battery to extend a transportation range of the refuse vehicle.

(3) Another embodiment relates to a range extension system for a refuse vehicle. The range extension system includes a battery, and a controller. The battery is configured to provide electrical energy for accessories of the refuse vehicle. The controller is configured to obtain a state of charge of the battery and limit operation of at least one of the accessories in response to the state of charge of the battery to extend a transportation range of the refuse vehicle.

(4) Another embodiment of the present disclosure relates to a method for increasing a transportation range of a refuse vehicle. The method includes operating accessories of the refuse vehicle using energy provided by an electrical storage system (ESS). The method also includes obtaining a state of charge of the ESS, and in response to the state of charge of the ESS indicating an insufficient amount of energy is available, at least one of (i) limiting operation of at least one accessory of the refuse vehicle, or (ii) activating a supplemental energy source to charge the ESS. Limiting operation of at least one accessory of the refuse vehicle or activating the supplemental energy source increases the transportation range of the refuse vehicle. The method also includes, in response to the state of charge of the ESS indicating that a sufficient amount of energy is available, continuing to operate the accessories of the refuse vehicle using energy provided by the ESS without limiting operation of any of the accessories and without activating the supplemental energy source.

(5) This summary is illustrative only and is not intended to be in any way limiting. Other aspects, inventive features, and advantages of the devices or processes described herein will become apparent in the detailed description set forth herein, taken in conjunction with the accompanying figures, wherein like reference numerals refer to like elements.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a perspective view of a refuse vehicle including an independent accessory system, according to an exemplary embodiment.

(2) FIG. **2** is a block diagram of the independent accessory system of the refuse vehicle of FIG. **1**, according to an exemplary embodiment.

(3) FIG. **3** is a block diagram of a control system of the refuse vehicle of FIG. **1**, according to an exemplary embodiment.

(4) FIG. **4** is a block diagram of a charging system for the refuse vehicle of FIG. **1**, according to an exemplary embodiment.

(5) FIG. **5** is a perspective view of a support structure for fuel tanks of the independent accessory system of the refuse vehicle of FIG. **1**, according to an exemplary embodiment.

(6) FIG. **6** is a perspective view of the refuse vehicle of FIG. **1**, with an accessory power unit that contains some of the components of the independent accessory system of FIG. **1**, according to an exemplary embodiment.

(7) FIG. **7** is a block diagram of a range extension system of the refuse vehicle of FIG. **1**, according to an exemplary embodiment.
(8) FIG. **8** is a flow diagram of a process for extending range of a refuse vehicle, according to an exemplary embodiment.
(9) FIG. **9** is a diagram of a map showing a current location of the refuse vehicle of FIG. **1** along a collection route, which can be used to determine required amounts of energy for completing the collection route, according to an exemplary embodiment.
(10) FIG. **10** is a diagram showing a portion of the range extension system of FIG. **7** including a body controller and a chassis controller, according to some embodiments.
(11) FIG. **11** is a diagram showing a portion of the range extension system of FIG. **7**

DETAILED DESCRIPTION

(12) Before turning to the FIGURES, which illustrate certain exemplary embodiments in detail, it should be understood that the present disclosure is not limited to the details or methodology set forth in the description or illustrated in the FIGURES. It should also be understood that the terminology used herein is for the purpose of description only and should not be regarded as limiting.

Overview

(13) Referring generally to the FIGURES, a refuse vehicle includes a prime mover configured to drive the refuse vehicle for transportation. The refuse vehicle may include tractive elements (e.g., wheels) that are configured to be driven by the prime mover to transport the refuse vehicle from location to location. The prime mover can be an electric motor, a compressed natural gas (CNG) engine, an internal combustion engine (e.g., a diesel engine, a gasoline engine, etc.), or any combination thereof. For example, the refuse vehicle may be a hybrid refuse vehicle that includes both an electric motor and an internal combustion engine.
(14) The refuse vehicle also includes an independent accessory system that is configured to operate various body functions of the refuse vehicle. For example, the independent accessory system can be configured to operate lift arms, a packer apparatus, a tailgate, lifting/dumping apparatuses, etc., of the refuse vehicle. The independent accessory system can include one or more fuel tanks (e.g., pressure vessels) that store fuel (e.g., CNG fuel, diesel fuel, gasoline fuel, etc.) for use by an engine (e.g., an internal combustion engine). The fuel may be stored in the one or more fuel tanks as a liquid fuel, a gaseous fuel, or a combination thereof (e.g., a saturated fuel). The engine may be configured to fluidly couple with the fuel tanks to receive fuel from the tanks, combust the fuel, and drive a hydraulic pump. The hydraulic pump can draw or recirculate hydraulic fluid from a reservoir and provide the hydraulic fluid to one or more hydraulic cylinders. The hydraulic cylinders can be operated to perform various body functions (e.g., by extending and/or retracting).
(15) The independent accessory system can be operated by a user through a human machine interface (HMI) and a controller. The controller may receive user inputs from the HMI and generate control signals for the engine and/or the hydraulic pump to perform requested operations of the body functions. The engine and the hydraulic pump may be sized according to requirements of the various body functions. For example, a compaction apparatus that compacts, crushes, compresses, or otherwise packs refuse may require a larger hydraulic cylinder, hydraulic pump, and engine. Likewise, a smaller hydraulic cylinder, hydraulic pump, and engine may be suitable for lift arms for small refuse collection bins.
(16) In some embodiments, one or more of the components of the independent accessory system are positioned within a modular unit (e.g., a modular add-on unit, an accessory power unit, etc.). The modular unit can be removably coupled with the refuse vehicle. The modular unit can include the engine, the hydraulic pump, a reservoir for the hydraulic pump, etc. In some embodiments, the modular unit is configured to fluidly couple with the fuel tanks to receive the fuel from the fuel tanks. The modular unit can be removably and/or fixedly coupled anywhere on the refuse vehicle, and may be fluidly coupled with the fuel tanks.

(17) The prime mover of the refuse vehicle may be an electric motor. If the prime mover is an electric motor, the refuse vehicle may include a battery system having battery cells. The battery cells may store electrical energy (e.g., in the form of chemical energy) and provide the electrical energy to the electric motor for transportation. The battery system can be configured to removably electrically couple with a charging station that may be located at jobsites, along a route of the refuse vehicle, at charging locations, at a fleet management location (e.g., a home base), etc. The charging station can include an engine, a generator, and fuel tanks. The fuel tanks can provide the engine with fuel. The engine combusts the fuel and drives the generator (e.g., through a shaft). The generator then charges the batteries with electrical power/electrical energy that can be used to transport the refuse vehicle.
(18) Overall Vehicle
(19) As shown in FIG. **1**, a vehicle, shown as refuse vehicle **10** (e.g., a garbage truck, a waste collection truck, a sanitation truck, a recycling truck, etc.), is configured as a front-loading refuse truck. In other embodiments, the refuse vehicle **10** is configured as a side-loading refuse truck or a rear-loading refuse truck. In still other embodiments, the vehicle is another type of vehicle (e.g., a skid-loader, a telehandler, a plow truck, a boom lift, etc.). As shown in FIG. **1**, the refuse vehicle **10** includes a chassis, shown as frame **12**; a body assembly, shown as body **14**, coupled to the frame **12** (e.g., at a rear end thereof, etc.); and a cab, shown as cab **16**, coupled to the frame **12** (e.g., at a front end thereof, etc.). The cab **16** may include various components to facilitate operation of the refuse vehicle **10** by an operator (e.g., a seat, a steering wheel, actuator controls, a user interface, switches, buttons, dials, etc.).
(20) As shown in FIG. **1**, the refuse vehicle **10** includes an electric motor, a CNG engine, a hybrid engine, an internal combustion engine, a diesel engine, a gasoline engine, etc., shown as prime mover **18**, and an energy storage system, shown as battery system **20**. In some embodiments, the prime mover is or includes an internal combustion engine. For example, the prime mover may be a diesel engine, a gasoline engine, a CNG engine, etc. According to the exemplary embodiment shown in FIG. **1**, the prime mover **18** is coupled to the frame **12** at a position beneath the cab **16**. The prime mover **18** is configured to provide power to a plurality of tractive elements, shown as wheels **22** (e.g., via a drive shaft, axles, etc.). In other embodiments, the prime mover **18** is otherwise positioned and/or the refuse vehicle **10** includes a plurality of electric motors to facilitate independently driving one or more of the wheels **22**. In still other embodiments, the prime mover **18** or a secondary electric motor is coupled to and configured to drive a hydraulic system that powers hydraulic actuators. According to the exemplary embodiment shown in FIG. **1**, the battery system **20** is coupled to the frame **12** beneath the body **14**. In other embodiments, the battery system **20** is otherwise positioned (e.g., within a tailgate of the refuse vehicle **10**, beneath the cab **16**, along the top of the body **14**, within the body **14**, etc.).
(21) According to an exemplary embodiment, the battery system **20** is configured to provide electric power to (i) the prime mover **18** to drive the wheels **22**, (ii) electric actuators of the refuse vehicle **10** to facilitate operation thereof (e.g., lift actuators, tailgate actuators, packer actuators, grabber actuators, etc.), and/or (iii) other electrically operated accessories of the refuse vehicle **10** (e.g., displays, lights, etc.). In some embodiments, the refuse vehicle **10** includes an internal combustion generator that utilizes one or more fuels (e.g., gasoline, diesel, propane, natural gas, hydrogen, etc.) to generate electricity to charge the battery system **20**, power the prime mover **18**, power the electric actuators, and/or power the other electrically operated accessories (e.g., a hybrid refuse vehicle, etc.). For example, the refuse vehicle **10** may have an internal combustion engine augmented by the prime mover **18** to cooperatively provide power to the wheels **22**. The battery system **20** may thereby be charged via an on-board generator (e.g., an internal combustion generator, a solar panel system, etc.), from an external power source (e.g., overhead power lines, mains power source through a charging input, etc.), and/or via a power regenerative braking system, and provide power to the electrically operated systems of the refuse vehicle **10**.

(22) According to an exemplary embodiment, the refuse vehicle **10** is configured to transport refuse from various waste receptacles within a municipality to a storage and/or processing facility (e.g., a landfill, an incineration facility, a recycling facility, etc.). As shown in FIG. **1**, the body **14** includes a plurality of panels, shown as panels **32**, a tailgate **34**, and a cover **36**. The panels **32**, the tailgate **34**, and the cover **36** define a collection chamber (e.g., hopper, etc.), shown as refuse compartment **30**. Loose refuse may be placed into the refuse compartment **30** where it may thereafter be compacted (e.g., by a packer system, etc.). The refuse compartment **30** may provide temporary storage for refuse during transport to a waste disposal site and/or a recycling facility. In some embodiments, at least a portion of the body **14** and the refuse compartment **30** extend above or in front of the cab **16**. According to the embodiment shown in FIG. **1**, the body **14** and the refuse compartment **30** are positioned behind the cab **16**. In some embodiments, the refuse compartment **30** includes a hopper volume and a storage volume. Refuse may be initially loaded into the hopper volume and thereafter compacted into the storage volume by a compacting apparatus **46**. According to an exemplary embodiment, the hopper volume is positioned between the storage volume and the cab **16** (e.g., refuse is loaded into a position of the refuse compartment **30** behind the cab **16** and stored in a position further toward the rear of the refuse compartment **30**, a front-loading refuse vehicle, a side-loading refuse vehicle, etc.). In other embodiments, the storage volume is positioned between the hopper volume and the cab **16** (e.g., a rear-loading refuse vehicle, etc.).
(23) As shown in FIG. **1**, the refuse vehicle **10** includes a lift mechanism/system (e.g., a front-loading lift assembly, etc.), shown as lift assembly **40**, coupled to the front end of the body **14**. In other embodiments, the lift assembly **40** extends rearward of the body **14** (e.g., a rear-loading refuse vehicle, etc.). In still other embodiments, the lift assembly **40** extends from a side of the body **14** (e.g., a side-loading refuse vehicle, etc.). As shown in FIG. **1**, the lift assembly **40** is configured to engage a container (e.g., a residential trash receptacle, a commercial trash receptacle, a container having a robotic grabber arm, etc.), shown as refuse container **60**. The lift assembly **40** may include various actuators (e.g., electric actuators, hydraulic actuators, pneumatic actuators, etc.), shown as hydraulic cylinders **108**, to facilitate engaging the refuse container **60**, lifting the refuse container **60**, and tipping refuse out of the refuse container **60** into the hopper volume of the refuse compartment **30** through an opening in the cover **36** or through the tailgate **34**. The lift assembly **40** may thereafter return the empty refuse container **60** to the ground. According to an exemplary embodiment, a door, shown as top door **38**, is movably coupled along the cover **36** to seal the opening thereby preventing refuse from escaping the refuse compartment **30** (e.g., due to wind, bumps in the road, etc.).
(24) Accessory Power System
(25) Referring still to FIG. **1**, the refuse vehicle **10** also includes an independent accessory system **100** (e.g., a CNG powered accessory system, a diesel powered accessory system, etc.), according to an exemplary embodiment. The independent accessory system **100** can be configured to drive, move, provide mechanical energy for, etc., or otherwise operate various body functions of refuse vehicle **10** independently of an operation of prime mover **18**. For example, the independent accessory system **100** can be configured to drive or operate the lift assembly **40**, a tailgate lift assembly **42**, etc., or any other body function, lift apparatus, auxiliary apparatus, etc., of the refuse vehicle **10**. In some embodiments, the independent accessory system **100** is configured to operate a hydraulic cylinder **108** of any of the lift apparatuses, auxiliary apparatuses, etc. The independent accessory system **100** may be configured to operate independently of the prime mover (e.g., prime mover **18**) of the refuse vehicle **10**. In some embodiments, the independent accessory system **100** can operate to drive the hydraulic cylinders **108** without requiring operation of the prime mover **18**. For example, the independent accessory system **100** can independently provide mechanical energy for the various body functions **114** of the refuse vehicle **10**, without requiring operation of or mechanical energy from the prime mover **18** (e.g., even if prime mover **18** is shut-off or inoperational, or in an idle mode). In some embodiments, the independent accessory system **100**

and operation of the prime mover **18** are linked (e.g., linked in a control scheme). However, if operation of the independent accessory system **100** and the prime mover **18** are linked in a control scheme, the independent accessory system **100** and the prime mover **18** (e.g., the prime mover of the refuse vehicle **10**) may still be able to provide mechanical energy for their respective functions (e.g., operation of the body functions **114** and transportation of the refuse vehicle **10**, respectively) independent of the operation of each other.

(26) The body functions can include operation of lift arms (e.g., front loading lift arms, side loading lift arms, rear loading lift arms), tailgates, dumping operations, packing operations, etc., of the refuse vehicle **10**. The refuse vehicle **10** can include various hydraulic cylinders **108** configured to perform any of the body functions described herein. For example, the refuse vehicle **10** can include the compacting apparatus **46** that is configured to pack, crush, compact, compress, etc., refuse that is loaded into the hopper or the body **14** using the hydraulic cylinders **108**. The independent accessory system **100** can be configured to operate any of the hydraulic cylinders **108** to perform the various body functions in response to user inputs. The independent accessory system **100** can be configured to perform the various body functions independently of each other, or in conjunction with each other.

(27) Referring to FIGS. **1** and **2**, the independent accessory system **100** includes one or more tanks, capsules, containers, pressure vessels, cartridges, etc., shown as fuel tanks **104** (e.g., CNG tanks, diesel fuel tanks, gasoline tanks, etc.). The fuel tanks **104** are supported, fixedly coupled, fixed, connected, etc., or otherwise coupled with a support unit, a mount unit, a structure, etc., shown as support structure **102** of the refuse vehicle **10**. In some embodiments, the fuel tanks **104** are positioned within the tailgate **34** (e.g., as shown in FIG. **5**, described in greater detail below). For example, the fuel tanks **104** and the support structure **102** can be disposed within an inner volume of the tailgate **34**.

(28) The independent accessory system **100** also includes an internal combustion engine, a CNG engine, a diesel engine, a fuel cell, a hydrogen engine, an electric motor, etc., shown as accessory prime mover **110**. The accessory prime mover **110** is configured to receive fuel (e.g., diesel fuel, gasoline, CNG, hydrogen, electrical energy, a resource, etc.) from the fuel tanks **104** through a piping system, a plumbing system, one or more pipes, etc. The piping system can include various tubular members, pipes, hoses, valves, connectors, etc., that fluidly couple with the tank **112** and the accessory prime mover **110** such that fuel can be provided from the tank **112** to the accessory prime mover **110**. The accessory prime mover **110** can use the fuel (e.g., combust the fuel) to produce mechanical energy. The mechanical energy is output by the accessory prime mover **110** to a pump **106**. The pump **106** can be driven by the accessory prime mover **110** and draw hydraulic fluid from a fluid reservoir, a tank, etc., shown as tank **112**. The tank **112** is coupled with (e.g., fixedly coupled, attached, mounted, etc.) with the refuse vehicle **10**. The tank **112** can be fixedly coupled with the body **14**. The pump **106** outputs the hydraulic fluid to the hydraulic cylinders **108** to operate the hydraulic cylinders **108** to perform the body functions **114**.

(29) In some embodiments, the accessory prime mover **110** is a smaller engine than the prime mover **18**. The accessory prime mover **110** and the hydraulic pump **106** can be sized according to requirements of the various body functions. Other refuse vehicles use the prime mover **18** to drive the body functions. However, this may be inefficient, since the prime mover **18** is sized to transport the refuse vehicle **10** (e.g., to provide torque to the wheels **22**) and may be oversized for the body functions. Using a smaller engine (e.g., the accessory prime mover **110**) with a correspondingly sized hydraulic pump **106** facilitates a more efficient and robust refuse vehicle, which does not use an oversized prime mover **18** for body functions.

(30) Advantageously, the independent accessory system **100** can use pre-existing infrastructure of the refuse vehicle **10**. For example, CNG-powered refuse vehicles (e.g., refuse vehicles that use a CNG engine as the prime mover for transportation purposes) may already include a support structure and fuel tanks that can be used by the accessory prime mover **110**/hydraulic pump **106** for

the body functions.
(31) Accessory Power Unit
(32) Referring particularly to FIG. **6**, one or more portions of the independent accessory system **100** can be contained in, enclosed in, supported by, etc., a modular unit, an add-on unit, a removable unit, etc., shown as accessory power unit (APU) **120**. The APU **120** can be configured to integrate with existing infrastructure (e.g., CNG infrastructure) of the refuse vehicle **10** to operate or drive the various body functions of the refuse vehicle **10**. The refuse vehicle **10** can be configured as a front loading refuse vehicle, a side loading refuse vehicle, a rear loading refuse vehicle, etc. It should be understood that while the inventive concepts described herein reference a refuse vehicle, it is contemplated that the APU **120** and/or the various components of the independent accessory system **100** are also applicable to various other types of vehicles that include body functions. For example, the independent accessory system **100** and/or the APU **120** can be used on a fire truck, a commercial truck, a heavy-duty truck, etc., or any vehicle that has body functions to be operated independently of the transportation of the vehicle.
(33) The APU **120** can be removably coupled with the refuse vehicle **10** on an underside of the body **14**. For example, the APU **120** can be fixedly and removably coupled with the frame **12** beneath the body **14**. The APU **120** can be fixedly and removably coupled at a front of the frame **12**, at a rear end of the frame **12**, centrally along the frame **12**, etc. In other embodiments, the APU **120** can be fixedly and removably coupled with a side of the body **14**, within the body **14**, within a compartment of the body **14**, on top of the body **14**, etc. The APU **120** can be positioned anywhere about the body **14** or anywhere on the refuse vehicle **10** that provides sufficient structural strength (e.g., along the frame **12**, near a chassis of the refuse vehicle **10**, etc.).
(34) The APU **120** includes the accessory prime mover **110**, the tank **112**, and the hydraulic pump **106**, according to an exemplary embodiment. The APU **120** can be a hollow container that protects the various internal components (e.g., the accessory prime mover **110**, the tank **112**, the hydraulic pump **106**, etc.) and removably couples with the refuse vehicle **10**. The accessory prime mover **110** of the APU **120** fluidly couples with the fuel tanks **104** through a plumbing system, a piping system, etc., shown as tubular system **122**. The tubular system **122** includes various tubular members that fluidly couple the fuel tanks **104** with the accessory prime mover **110**. The accessory prime mover **110** receives the fuel from the fuel tanks **104** through the tubular system **122**, combusts the fuel, and drives the hydraulic pump **106**. The hydraulic pump **106** then drives the hydraulic cylinder(s) **108** of the various body functions of the refuse vehicle **10** (e.g., through various tubular members, pipes, etc.).
(35) Advantageously, the APU **120** facilitates a versatile refuse vehicle with improved efficiency since the accessory prime mover **110** and the hydraulic pump **106** are sized to serve or drive the various hydraulic cylinders **108**. The APU **120** can be installed by a technician, plumbed (e.g., by fluidly coupling the accessory prime mover **110** with the fuel tanks **104** through installation of the tubular system **122**), and used to operate the various body functions of the refuse vehicle **10**. Advantageously, the various body functions of the refuse vehicle **10** can be operated independently of the prime mover **18**. The APU **120** can integrate with existing structure (e.g., existing fuel tanks **104**), to thereby convert refuse vehicles to the refuse vehicle **10** described herein.
(36) Control System
(37) Referring particularly to FIG. **3**, a control system **200** can be configured to operate the refuse vehicle **10**, according to an exemplary embodiment. The control system **200** includes a controller that is configured to generate control signals for a drivetrain, a chassis, etc., of the refuse vehicle **10**, shown as drivetrain **210**. The drivetrain **210** includes an engine **202**, a transmission **204**, and wheels **22** of the refuse vehicle **10**. The engine **202** may be the prime mover **18** of the refuse vehicle **10**. The engine **202** can produce mechanical energy and output the mechanical energy to the transmission **204**. The transmission **204** receives the mechanical energy from the engine **202** and outputs mechanical energy (e.g., rotational kinetic energy) to the wheels **22** (e.g., at a higher torque

than the mechanical energy input by the engine **202**).
(38) Control system **200** includes a controller **208** that is configured to generate control signals for the engine **202** and the transmission **204**. The controller **208** can include a circuit, shown as processing circuit **216**, a processor, shown as processor **212**, and memory, shown as memory **214**, according to an exemplary embodiment. Controller **208** may be implemented as a general-purpose processor, an application specific integrated circuit (ASIC), one or more field programmable gate arrays (FPGAs), a digital-signal-processor (DSP), circuits containing one or more processing components, circuitry for supporting a microprocessor, a group of processing components, or other suitable electronic processing components. The processing circuit **216** of controller **208** may include an ASIC, one or more FPGAs, a DSP, circuits containing one or more processing components, circuitry for supporting a microprocessor, a group of processing components, or other suitable electronic processing components (i.e., processor **212**). In some embodiments, the processing circuit **216** is configured to execute computer code stored in memory **214** to facilitate the activities described herein.
(39) Memory **214** may be any volatile or non-volatile computer-readable storage medium capable of storing data or computer code relating to the activities described herein. According to an exemplary embodiment, memory **214** includes computer code modules (e.g., executable code, object code, source code, script code, machine code, etc.) configured for execution by the processing circuit **216**.
(40) In some embodiments, a single controller **208** is configured to generate control signals for both the drivetrain **210** and the independent accessory system **100**. In other embodiments, multiple controllers **208** are configured to generate control signals for independent accessory system **100** and drivetrain **210** independently of each other. For example, a first controller **208** can be configured to provide control signals to engine **202** and/or transmission **204** of drivetrain **210**, while a second controller **208** can be configured to provide control signals for independent accessory system **100**. The first and second controllers **208** can be configured to receive user inputs from a human machine interface (HMI) or a user interface, shown as HMI **218**. In some embodiments, the first and second controllers **208** are configured to receive user inputs from separate HMIs **218**. The HMIs **218** can be positioned within the cab **16** or near the associated body functions (e.g., near lift assembly **40**). For example, the HMI **218** that controls the operation of the drivetrain **210** can be disposed within the cab **16**, while the HMI **218** that controls the operation of the lift assembly **40** can be positioned on the body **14** near the lift assembly **40**.
(41) Charging System
(42) Referring particularly to FIG. **4**, a charging system **300** can be used to re-charge batteries **44** of the battery system **20**, according to an exemplary embodiment. The charging system **300** includes a charging station **302** that can be positioned at a fleet management site, at a job site, along the refuse vehicle's route, etc. The charging station **302** includes one or more fuel tanks **306**, an engine **304**, and a generator **308**. The fuel tanks **306** can be the same as or similar to the fuel tanks **104** on the refuse vehicle **10**. Likewise, the engine **304** can be similar to the accessory prime mover **110** on the refuse vehicle **10**.
(43) The refuse vehicle **10** includes controller **208** that is configured to generate and provide control signals for prime mover **18** (e.g., an electric motor) and/or accessory prime mover **110**. The controller **208** can be configured to receive user inputs from HMI **218** and generate the control signals for the prime mover **18** and/or the accessory prime mover **110** based on the user inputs. In some embodiments, the controller **208** generates control signals to operate the prime mover **18** and/or the accessory prime mover **110** to perform operations requested by the user through HMI **218**.
(44) The refuse vehicle **10** can be driven by an electric motor, an engine (e.g., engine **202**), or a hybrid engine-electric motor. In this way, the refuse vehicle may be an electrically driven refuse vehicle, an internal-combustion engine driven vehicle, or a hybrid vehicle. For example, the refuse

vehicle **10** can include a plurality of prime movers. One or more of the prime movers can be electric motors (e.g., the prime mover **18**) and/or internal combustion engines (e.g., the engine **202**). The electric motors used to transport the refuse vehicle **10** are supplied with power by batteries **44** of the battery system **20**.

(45) The batteries **44** can be removable and/or replaceable battery cells. For example, the batteries **44** can be charged at a fleet management site in a charging rack, then installed into the refuse vehicle **10**. The batteries **44** can be later removed (e.g., after a state of charge of the batteries **44** has been depleted) and replaced with new or fresh batteries (e.g., that may be stored on the refuse vehicle **10**).

(46) The operator of the refuse vehicle **10** may arrive at a job site, or at a fleet management location and electrically couple the charging station **302** with the batteries **44**. Since some refuse vehicles operate using CNG, the charging station **302** may use pre-existing fuel tanks **306** at the fleet management location that store CNG. In some embodiments, the engine **304** and the generator **308** are packaged in a unit that is configured to fluidly couple with the fuel tanks **306**. In some embodiments, the fuel tanks **306** are removably fluidly coupled with the engine **304**. In this way, the fuel tanks **306** can be used for replenishing the fuel tanks **104** on the refuse vehicle **10** and/or for charging batteries **44** of the refuse vehicle **10**. The generator **308** can be any mechanical transducer capable of receiving mechanical energy (e.g., rotational kinetic energy) and generating electrical energy for the batteries **44**. For example, the generator **308** can include a stator and an armature that is driven by the engine **304** to produce electrical current or electrical energy.

(47) Referring again to FIG. **2**, the accessory prime mover **110** can be configured to output mechanical energy to a generator **116** to drive generator **116** to generate electrical power. The electrical power is provided to batteries **44** of refuse vehicle **10** to charge the batteries **44**. In this way, accessory prime mover **110** can operate independently to drive generator **116** to charge batteries **44** of refuse vehicle **10**.

(48) Support Infrastructure

(49) Referring now to FIG. **5**, one possible infrastructure of the support structure **102** includes the fuel tanks **104** stored within the tailgate **34**. The tailgate **34** can include a first or inner member **502** and a second or outer member **504**. The first member **502** is configured to fixedly and/or pivotally couple with the refuse vehicle **10**. The first member **502** and the second member **504** can be configured to removably and fixedly couple with each other to define an inner volume. The fuel tanks **104** can be fixedly coupled with the first member **502** and stored within the inner volume defined by the first member **502** and the second member **504**. The fuel tanks **104** can be oriented horizontally (as shown in FIG. **5**) or vertically. The fuel tanks **104** can be fixedly coupled with the first member **502** at their ends (e.g., with fasteners). In some embodiments, the fuel tanks **104** extend along substantially an entire width of the tailgate **34**.

(50) It should be understood that while several configurations of the support structure **102** are described herein, the inventive concepts are not limited to these configurations of the support structure **102**. The fuel tanks **104** can be positioned anywhere on the refuse vehicle **10**, or in multiple locations. For example, the fuel tanks **104** can be positioned on top of the refuse vehicle **10** (e.g., on top of the body **14**), underneath the refuse vehicle **10** (e.g., on an underside of the body **14**, on the frame **12** beneath the refuse vehicle **10**, etc.), between the cab **16** and the body **14**, etc.

(51) Range Extension

(52) Referring to FIGS. **7** and **8**, the refuse vehicle **10** or systems thereof are configured to implement range extension to limit operations of various body functions or accessories of the refuse vehicle **10**. In an exemplary embodiment, a control system or controller of the refuse vehicle **10** monitors charge level, state of charge, energy level, etc., of the batteries **44** and limits operation of various body functions or accessories of the refuse vehicle **10** (e.g., limiting operation of a compaction apparatus of the refuse vehicle, limiting tailgate operations, etc.) to prolong life of the batteries **44** for transportation of the refuse vehicle **10** (e.g., so that the refuse vehicle **10** can return

to a location, finish a route, etc.). In some embodiments, the independent accessory system **100** or components thereof are configured to operate to charge the batteries **44** as required based on state of charge or remaining energy level of the batteries **44**.

(53) Referring particularly to FIG. **7**, the refuse vehicle **10** includes a range extension system **700** as shown. The range extension system **700** can include the independent accessory system **100** or components thereof (e.g., APU **120**). As shown in FIG. **7**, the range extension system **700** includes the controller **208**, the battery system **20**, accessories **702** and a supplemental energy source **708** (e.g., the APU **120**). The range extension system **700** can also include the HMI **218** that is configured to provide user inputs to the controller **208** for operation of the refuse vehicle **10**, chassis functions, body functions, etc., thereof. The range extension system **700** can also include a global positioning system (GPS) **706** that is configured to provide GPS data (e.g., latitude and longitude, current geographical location/position, etc.) to the controller **208**.

(54) The controller **208** is configured to receive data from the battery system **20** or from the batteries **44** of the refuse vehicle **10**, that indicates or includes a charge level, an amount of energy in the batteries **44**, a remaining amount of power that can be provided or discharged, etc. In some embodiments, the controller **208** is configured to receive the data from the battery system **20** (e.g., a charge level of the batteries **44** as shown), and determine if operation of one or more of the accessories **702** should be limited, restricted, etc., based on the charge level of the batteries **44**. In some embodiments, the controller **208** is configured to compare the charge level of the batteries **44** to one or more thresholds and, when the charge level exceeds or decreases below various of the one or more thresholds, limit operation of corresponding one or more accessories **702** of the refuse vehicle **10** (e.g., limit unnecessary body operations). In some embodiments, the controller **208** is a body controller of the refuse vehicle **10**, a chassis controller of the refuse vehicle **10**, a main controller of the refuse vehicle **10**, etc.

(55) As shown in FIG. **7**, the refuse vehicle **10** includes accessories **702**, shown to include accessory **702***a*, accessory **702***b*, accessory **702***c*, etc., and accessory **702***n*. It should be understood that the accessories **702** can include any number of accessories **702***a* . . . **702***n*. Each of the accessories **702** includes a corresponding electric motor, electric linear actuator, controller, processing circuitry, etc., shown as electrical components **704***a* . . . **704***n*. In some embodiments, any of the accessories **702** include multiple electrical components **704**. The electrical components **704** may include lights, speakers, alert devices, electric motors, etc., or any other electrical component that consumes electrical energy during operation of the accessories **702**. For example, if the accessory **702***a* is a compaction system, the electrical component **704***a* of the accessory **702***a* may be an electric linear actuator or an electric motor that is configured to consume electrical energy (e.g., provided by the battery system **20**) and use the electrical energy to drive the compaction apparatus. Similarly, if the accessory **702***b* is a reach arm or a loading apparatus, the electric components **704***b* may be a linear electric actuator that consumes electrical energy provided by the battery system **20** and uses the electrical energy to drive the reach arm or loading apparatus to perform various loading operations. In another example, if the accessory **702***c* is a lighting system (e.g., body lights, headlights, etc.), the electrical components **704***c* of the accessory **702***c* may be light emitting diodes (LEDs), etc., that consume electrical energy provided by the battery system **20** and use the electrical energy to provide lighting operations. It should be understood that the accessories **702** can include any body, chassis, cab, accessory, etc., systems, sub-systems, components, etc., including but not limited to body lights, headlights, torque converters, electric transmissions, generators, electric actuators, reach arms, lift apparatuses, tailgate apparatuses, compaction apparatuses, GPS system, driver monitor system, autonomous driving system, camera systems, etc.

(56) Referring still to FIG. **7**, the controller **208** is configured to receive a user input from the HMI **218** (e.g., a control input) and operate the accessories **702** based on the user input provided by the HMI **218**. In some embodiments, the controller **208** generates the control signals for the accessories

702 based on the user input and provides the control signals to corresponding or appropriate ones of the accessories **702**. In some embodiments, the accessories **702** receive the control signals from the controller **208**, operate based on the control signals, and consume energy from the battery system **20** to perform a requested operation as indicated by the user input and provided by the control signals.

(57) The controller **208** is also configured to generate control signals for the prime mover **18** or for various chassis functions or devices for transportation of the refuse vehicle **10**. In an exemplary embodiment, the controller **208** operates the prime mover **18** and the accessories **702** such that a requested function (e.g., a drive operation, operation of a compaction apparatus, etc.) is performed by the prime mover **18** or by the accessories **702**.

(58) When the controller **208** identifies, based on the charge level as provided by the battery system **20**, that one or more of the accessories **702** should be limited in function to conserve energy, the controller **208** may generate and provide control signals the one or more accessories **702** that causes the one or more accessories to stop operating, or may cease providing control signals to the one or more accessories **702** that should be limited in function. In some embodiments, when the controller **208** identifies that the one or more accessories should be limited in operation, the controller **208** stops generating control signals for the accessories **702** that should be limited in operation, even if a user provides a user input to control those accessories **702**. The controller **208** may also operate one or more display devices (e.g., liquid crystal displays (LCDs), light emitting diodes (LEDs), etc.) to notify an operator or user of the refuse vehicle **10** that one or more of the accessories **702** are limited in operation, and specifically which of the one or more accessories **702** have been limited in operation, and why the one or more accessories **702** are limited in operation (e.g., displaying remaining charge level in the batteries **44**).

(59) In some embodiments, limiting operation of one or more accessories **702** includes changing a periodicity of operation of the limited operation accessories **702**. For example, if the controller **208** determines that the operation of a compaction apparatus should be limited (e.g., the accessory **702***b*), the controller **208** may increase a time period between subsequent compaction operations. If the compaction apparatus operates after a particular number of stops, or after every time refuse is loaded into the hopper under normal operating conditions, the compaction apparatus may be transitioned into a limited operational mode where the compaction apparatus operates after an increased number of stops, after multiple times refuse is loaded into the hopper, etc. In this way, the accessories **702** may still be operational when limited by the controller **208** due to the charge level of the batteries **44** being low, but operated less frequently.

(60) In some embodiments, the controller **208** may also be configured to receive an override from the HMI **218** or from input device(s) **710** (e.g., buttons, levers, dials, touchscreen displays, user devices, mobile devices, etc.) thereof. The override may remove the limitation on operation of the one or more accessories **702** to thereby allow the user or operator to control the limited operation accessories **702** (e.g., temporarily) to perform necessary tasks. In some embodiments, the controller **208** defaults back to limiting operation of the one or more accessories **702** after a certain amount of time or after the user has performed a certain function. In some embodiments, the controller **208** is configured to operates the accessories **702** into a resting state immediately prior to limiting function of one or more of the accessories **702**.

(61) Referring still to FIG. **7**, the battery system **20**, or more particularly, the supplemental energy source **708** is configured to provide supplemental energy to the batteries **44** when required, according to an exemplary embodiment. The supplemental energy source **708** may be or include an auxiliary power pack, a fuel cell, a generator driven by a fuel cell, etc. In some embodiments, the supplemental energy source **708** includes the fuel tanks **104**, the accessory prime mover **110**, and the generator **116**. For example, when the supplemental energy source **708** is required, the accessory prime mover **110** may consume fuel (e.g., CNG) provided by the tanks **104**, drive the generator **116**, and provide generated electrical energy as the supplemental energy to the batteries

44, or directly to the prime mover **18** (e.g., for transportation of the refuse vehicle **10** or for charging the batteries **44** so that the prime mover **18** can consume energy provided by the batteries **44** to drive the wheels **22**). In some embodiments, the supplemental energy source **708** is only activated or used when a state of charge or charge level of the batteries **44** decreases below a particular level (e.g., when energy available at the batteries **44** is insufficient for use in transporting the refuse vehicle **10** to a charging station, to a home base, to complete a route, etc.). The supplemental energy source **708** may be configured to provide supplemental energy to the battery system **20** to charge the batteries **44**, or may operate in parallel with the battery system **20** to provide supplemental energy directly to the prime mover **18** (e.g., when a state of charge of the batteries **44** are low). Referring still to FIG. **7**, the supplemental energy source **708** can be configured to provide hydraulic power to the accessories **702**. For example, if one or more of the accessories **702** consume hydraulic power to operate, the supplemental energy source **708** may provide hydraulic power to the one or more accessories **702** that use hydraulic power to operate.

(62) Advantageously, one or more of the accessories **702** can be limited in operation and the supplemental energy source **708** can be activated (e.g., by the controller **208** or by providing control signals to the controller **208**) when required for transportation purposes of the refuse vehicle **10**. Limiting the operation of one or more of the accessories **702** and activating the supplemental energy source **708** can extend a range of the refuse vehicle **10**. In some embodiments, thresholds of the charge level (e.g., the state of charge) of the batteries **44** are adjustable based on the GPS data provided by the GPS **706**, driving habits of the driver, historical data of energy usage of the particular refuse vehicle **10**, etc.

(63) Referring to FIG. **8**, a process **800** for operating a refuse vehicle for range extension (e.g., by limiting operation of various body or accessory functions, or by activating a supplemental energy source) is shown, according to an exemplary embodiment. The process **800** includes steps **802-816** and may be performed by the controller **208** or more generally by the range extension system **700** of the refuse vehicle **10**. The process **800** can be performed so that the refuse vehicle **10** has sufficient capabilities or the ability to return safely to a home base, to a charging station, to extend a transportation range of the refuse vehicle **10**, etc.

(64) The process **800** includes operating accessories of an electric refuse vehicle using energy provided by an electrical storage system (ESS) of the electric refuse vehicle (step **802**), according to some embodiments. In some embodiments, the accessories include various body functions, lifting apparatuses, compaction apparatuses, etc., of the electric refuse vehicle that consume electrical energy. In some embodiments, the accessories include any lighting, accessory, radio, wireless communications, driver monitoring systems, telematics, etc., of the electric refuse vehicle. More generally, the accessories can include any components, devices, systems, sub-systems, etc., that consume electrical energy to operate. The accessories can consume electrical energy provided by the ESS or batteries of the ESS that are on-board the electric refuse vehicle. The electric refuse vehicle may be the refuse vehicle **10** as described in greater detail above with reference to FIGS. **1-6**. In some embodiments, the ESS is the battery system **20**. In some embodiments, the accessories are the accessories **702** of the refuse vehicle **10**. In some embodiments, step **802** also includes operating one or more body functions, chassis functions, etc., or otherwise operating the electric refuse vehicle under normal conditions. For example, the step **802** may include, receiving at the controller **208**, a user input or a control input, and generating control signals for the accessories (e.g., body functions) and/or chassis functions according to the control input.

(65) The process **800** includes monitoring available energy in the ESS (step **804**), according to some embodiments. In some embodiments, step **804** is performed by the controller **208** or processing circuitry thereof by receiving a state of charge or a charge level from the ESS in real-time, intermittently, near real-time, periodically, etc. In some embodiments, step **804** and step **806** are performed simultaneously or concurrently with each other. In some embodiments, step **804** includes obtaining the state of charge from the ESS and analyzing the state of charge to determine

if one or more of the accessories should be limited in operation.

(66) The process **800** includes determining if sufficient energy is available (step **806**), according to some embodiments. In some embodiments, the step **806** is performed by the controller **208** or processing circuitry thereof. In some embodiments, the step **806** includes comparing the state of charge, charge level, or available energy in the ESS to a threshold value. If the state of charge, charge level, or available energy is less than the threshold value (step **806**, “NO”), the process **800** proceeds to step **808**, according to some embodiments. If the state of charge, charge level, or available energy is greater the threshold value (step **806**, “YES”), the process **800** returns to step **802** and continues operating the electric refuse vehicle normally. In some embodiments, the threshold are preset or predetermined values. In some embodiments, the threshold is an adjustable parameter that is determined by the controller based on historical energy consumption of the electric refuse vehicle for transportation, driver habits, etc., so that the threshold is specific to the electric refuse vehicle (e.g., model, equipment, vehicle infrastructure, driver-specific, ESS capacity specific, etc.).

(67) The process **800** includes limiting operation of one or more accessories of the electric refuse vehicle to extend travel distance of the electric refuse vehicle (step **808**), according to some embodiments. In some embodiments, the step **808** is performed by the controller **208** in response to a determination that there is not sufficient energy available at the ESS (e.g., that the state of charge or available energy in the ESS is less than the threshold). In some embodiments, step **808** includes determining which of the accessories can be limited in operation to prolong a battery life or to increase a range of the electric refuse vehicle. For example, accessories such as a compaction apparatus may be limited if the controller **208** determines that such functions are unnecessary or can be limited. In some embodiments, the step **808** includes limiting control signals being provided to the one or more accessories that should be limited in operation or providing control signals to the one or more accessories to limit operation thereof. In some embodiments, limiting operation of one or more accessories of the electric refuse vehicle includes shutting off power to the one or more accessories (e.g., body functions) of the refuse vehicle.

(68) The process **800** includes operating a primary mover of the electric refuse vehicle to consume electrical energy provided by the ESS for transportation of the electric refuse vehicle (step **810**), according to some embodiments. In some embodiments, the step **810** includes providing electrical energy to the primary mover (e.g., an electric motor) from the ESS so that the electric refuse vehicle operates to transport (e.g., to a next jobsite, along a collection route, to return to a home base, to travel to a charging station, etc.). In some embodiments, the step **810** also includes providing energy from the ESS to one or more of the accessories that are not limited in their operation. In some embodiments, the step **810** is performed by generating control signals for the primary mover so that the primary mover consumes electrical energy and drives wheels or tractive elements of the electric refuse vehicle.

(69) The process **800** includes determining if the energy available in the ESS is below another threshold (step **812**), according to some embodiments. In some embodiments, the threshold used in step **812** is different than the threshold used in the step **806**. In some embodiments, the threshold used in step **812** is lower than the threshold used in the step **806**. In some embodiments, the threshold used in step **806** is a first charge level (e.g., a 50% charge level) and the threshold used in step **812** is a second charge level (e.g., a 20% charge level). When the state of charge of the ESS decreases below the first charge level, the controller **208** may limit operation of certain accessories to conserve energy in the ESS to extend a range of the electric vehicle. When the state of charge of the ESS decreases below the second charge level, the controller **208** may activate a supplemental energy source to provide auxiliary power for the electric refuse vehicle (see e.g., steps **814-816**). In some embodiments, the steps **808-810** and the steps **814-816** are performed simultaneously in response to the state of charge of the ESS decreasing below a single threshold (e.g., a 50% charge level). In some embodiments, in response to the state of charge of the ESS or batteries thereof

being below the threshold (step **812**, "YES"), the process **800** proceed to the step **814**. In some embodiments, in response to the state of charge of the ESS or batteries thereof being greater than the threshold (step **812**, "NO"), the process **800** returns to the step **810**.

(70) The process **800** includes operating a supplemental energy source to generate electrical energy (step **814**), according to some embodiments. In some embodiments, the supplemental energy source is or includes the APU **120**, an auxiliary power pack, a fuel cell, a generator driven by a fuel cell, engine, CNG engine, etc. In some embodiments, the supplemental energy source includes the fuel tanks **104**, the accessory prime mover **110**, and the generator **116**. For example, when the supplemental energy source is required, the accessory prime mover may consume fuel such as CNG that is provided by the tanks **104**, and drive a generator that generates electrical energy.

(71) The process **800** includes using the generated electrical energy to at least one of charge the ESS or to directly power the primary mover of the electric refuse vehicle (step **816**), according to some embodiments. In some embodiments, the generated electrical energy is provided to the batteries **44** of the battery system **20** to charge the batteries **44**. In some embodiments, the batteries **44** can then be discharged (e.g., concurrently with being charged by the generated electrical energy) and the discharged electrical energy is provided to the prime mover of the electric refuse vehicle, or to one or more of the accessories of the electric refuse vehicle so that a transportation range of the electric refuse vehicle is increased.

(72) Referring to FIG. **9**, a diagram **900** shows a map **902** illustrating a current location of the refuse vehicle **10** along a collection route **908**. The map **902** illustrates roads and city blocks along which refuse containers may be positioned for the refuse vehicle **10** to service (e.g., empty contents of the refuse containers into the hopper and transport collected refuse). The map **902** includes a charging station **906** (e.g., the charging station **302**) and a home base, landfill, etc., shown as home location **904**. The refuse vehicle **10** can return to the home location **904** when the route is completed and empty the contents of the body **14**. As shown in FIG. **9**, emptied containers **916** and unemptied containers **914** are positioned along the collection route **908**.

(73) Referring to FIGS. **7** and **9**, the GPS **706** can provide GPS data indicating a current location of the refuse vehicle **10** (e.g., a current location on the map **902**). The controller **208** may determine a relative distance **918** between the refuse vehicle **10** and the charging station **906** (or a closest of multiple charging stations **906**), and a relative distance **920** between the refuse vehicle **10** and the home location **904**. In some embodiments, a charging station is also positioned at the home location **904**. The controller **208** may determine a quickest route **910** from the current location of the refuse vehicle **10** to the charging station **906**, and a quickest route **912** from the current location of the refuse vehicle **10** to the home location **904**. In some embodiments, the controller **208** also includes (e.g., stored in memory thereof, provided by a remote communications or cloud system) the collection route **908** of the refuse vehicle **10**. If the controller **208** determines that the charge level of the batteries **44** is currently insufficient to complete transportation along the collection route **908**, the controller **208** may limit operation of one or more of the accessories **702**, activate the supplemental energy source **708**, etc. If the controller **208** determines that, even if the one or more accessories **702** are limited in operation and the supplemental energy source **708** is activated, that there is insufficient energy available to complete transportation of the refuse vehicle **10** along the collection route **908** (in combination with proper operation of the accessories **702** for collection of waste), the controller **208** may prompt the operator to either return along the quickest route **912** to the home location **904** for proper charging, or may prompt the operator to transport along the quickest route **910** to the nearest charging station **906** for charging the batteries **44** of the refuse vehicle **10** so that the collection route **908** can be completed. In this way, the controller **208** can use GPS data, route data, known locations of charging stations or landfills or home bases, etc., to determine if one or more of the accessories **702** should be limited in operation to increase range of the refuse vehicle **10** such that the collection route **908** can be completed.

(74) In some embodiments, the controller **208** uses a distance of the collection route **908**, historical

data indicating the driver's habits, specific information about the refuse vehicle **10**, an estimated number of stops along the collection route **908**, etc., to determine a required amount of energy that must be supplied by the batteries **44** and/or the supplemental energy source **708**. In some embodiments, the required amount of energy for completing the collection route **908** is set as or used to determine the thresholds (e.g., the first charge level and the second charge level, or the thresholds as described in greater detail above with reference to FIGS. **7-8**).

(75) It should be understood that the range extension system **700** as described herein with reference to FIGS. **7-8** is usable with a fully electric vehicle, a hybrid-electric vehicle, etc. For example, while FIG. **7** shows the battery system **20** providing electrical energy to the prime mover **18**, the prime mover **18** may also be an internal combustion engine that is configured to operate using fuel (e.g., gasoline, diesel, CNG, etc.), and the battery system **20** may be configured to provide electrical energy for the accessories **702** of the refuse vehicle **10**. Similarly, the prime mover **18** may be an electric motor that is configured to consume electrical energy provided by the battery system **20** (e.g., when the range extension system **700** is implemented in a fully-electric refuse vehicle).

(76) Referring to FIG. **10**, the controller **208** may be provided as or include a body controller **208***a* and a chassis controller **208***b*, according to an exemplary embodiment. The body controller **208***a* and the chassis controller **208***b* can be similar to each other (e.g., each including processing circuitry **216**, processor **212**, and memory **214**, etc.) but configured to operate body accessories **1002** and chassis accessories **1004**, respectively. In particular, the body controller **208***a* includes processing circuitry **216***a* having a processor **212***a* and memory **214***a*, and is configured to operate (e.g., based on a user input, based on a state of charge or energy level provided by the battery system **20**, etc.) the body accessories **1002**. Similarly, the chassis controller **208***b* includes processing circuitry **216***b* having a processor **212***b* and memory **214***b*, and is configured to operate (e.g., based on a user input, based on a state of charge or energy level provided by the battery system **20**, etc.) the chassis accessories **1004**.

(77) In some embodiments, the body controller **208***a* and the chassis controller **208***b* are configured to operate similarly to the controller **208** as described in greater detail above with reference to FIG. **7**. In some embodiments, the battery system **20** includes body batteries **44***a* and chassis batteries **44***b*. The body batteries **44***a* are configured to provide electrical energy for consumption or use by the body accessories **1002** (e.g., accessory **1002***a*, accessory **1002***b*, accessory **1002***c*, . . . , accessory **1002***n*, etc.), and the chassis batteries **44***b* are configured to provide electrical energy for consumption or use by the chassis accessories **1004** (e.g., accessory **1004***a*, accessory **1004***b*, accessory **1004***c*, . . . , accessory **1004***n*, etc.). The body batteries **44***a* and the chassis batteries **44***b* may configured to exchange electrical energy therebetween the body batteries **44***a* and the chassis batteries **44***b* such that when the body batteries **44***a* are low in energy, the chassis batteries **44***b* may charge the body batteries **44***a* or vice versa. The body accessories **1002** and the chassis accessories **1004** can be the same as or similar to any of the accessories **702** as described in greater detail above with reference to FIG. **7**.

(78) In some embodiments, the body controller **208** is configured to receive a state of charge of the body batteries **44***a* and the chassis controller **208***b* is configured to receive a state of charge of the chassis batteries **44***b* from the battery system **20**. The body controller **208***a* can limit operation of the body accessories **1002** (e.g., using any of, or any similar techniques as described in greater detail above with reference to FIG. **7**) based on the state of charge of the body batteries **44***a*, and the chassis controller **208***b* can limit operation of the chassis accessories **1004** (e.g., using any of, or any similar techniques as described in greater detail above with reference to FIG. **7**) based on the state of charge of the chassis batteries **44***b*. In this way, the functionality of the controller **208** as described in greater detail above can be performed at the body controller **208***a* or the chassis controller **208***b* specifically for the body accessories **1002** or the chassis accessories **1004**. In some embodiments, the body controller **208***a* and/or the chassis controller **208***b* are configured to operate

cooperatively to limit operation of the body accessories **1002** or the chassis accessories **1004**. In some embodiments, the body controller **208***a* is configured to receive the state of charge from the body batteries **44***a* or the chassis batteries **44***b* and limit operation of the body accessories **1002** or the chassis accessories **1004**, or both. Similarly, the chassis controller **208***b* may be configured to receive the state of charge from the body batteries **44***a* or the chassis batteries **44***b* and limit operation of the body accessories **1002** or the chassis accessories **1004**, or both.

(79) Referring to FIG. **11**, a portion of the range extension system **700** shows an implementation of the supplemental energy source **708** for providing electrical energy to the battery system **20** (e.g., to the batteries **44**, the body batteries **44***a*, the chassis batteries **44***b*, etc.). In an exemplary embodiment, the supplemental energy source **708** includes fuel tanks **1102**, an internal combustion engine (ICE) **1104**, and a generator **1106**. The ICE **1104** may be a diesel ICE, a gasoline ICE, a CNG engine, etc., or any other ICE configured to receive fuel, combust the fuel, and output mechanical energy to a generator **1106**. In some embodiments, the fuel tanks **1102** are configured to store a fuel (e.g., gasoline, diesel, CNG, etc.) and provide the fuel to the ICE **1104**. In some embodiments, the ICE **1104** outputs the mechanical energy to the generator **1106** to drive the generator **1106** to generate electrical energy. The generated electrical energy can be provided to the battery system **20** (e.g., to the body batteries **44***a*, the chassis batteries **44***b*, etc.) to charge the batteries **44** of the battery system **20**, or alternatively to the prime mover **18** to provide additional electrical energy to the prime mover **18**. Advantageously, the supplemental energy source **708** can be provided as a generator set to generate electrical energy for charging the battery system **20** or for providing additional electrical energy to the prime mover **18** (e.g., when a state of charge of the battery system **20** is low or below a threshold).

Configuration of Exemplary Embodiments

(80) As utilized herein, the terms “approximately,” “about,” “substantially”, and similar terms are intended to have a broad meaning in harmony with the common and accepted usage by those of ordinary skill in the art to which the subject matter of this disclosure pertains. It should be understood by those of skill in the art who review this disclosure that these terms are intended to allow a description of certain features described and claimed without restricting the scope of these features to the precise numerical ranges provided. Accordingly, these terms should be interpreted as indicating that insubstantial or inconsequential modifications or alterations of the subject matter described and claimed are considered to be within the scope of the disclosure as recited in the appended claims.

(81) It should be noted that the term “exemplary” and variations thereof, as used herein to describe various embodiments, are intended to indicate that such embodiments are possible examples, representations, or illustrations of possible embodiments (and such terms are not intended to connote that such embodiments are necessarily extraordinary or superlative examples).

(82) The term “coupled” and variations thereof, as used herein, means the joining of two members directly or indirectly to one another. Such joining may be stationary (e.g., permanent or fixed) or moveable (e.g., removable or releasable). Such joining may be achieved with the two members coupled directly to each other, with the two members coupled to each other using a separate intervening member and any additional intermediate members coupled with one another, or with the two members coupled to each other using an intervening member that is integrally formed as a single unitary body with one of the two members. If “coupled” or variations thereof are modified by an additional term (e.g., directly coupled), the generic definition of “coupled” provided above is modified by the plain language meaning of the additional term (e.g., “directly coupled” means the joining of two members without any separate intervening member), resulting in a narrower definition than the generic definition of “coupled” provided above. Such coupling may be mechanical, electrical, or fluidic.

(83) References herein to the positions of elements (e.g., “top,” “bottom,” “above,” “below”) are merely used to describe the orientation of various elements in the FIGURES. It should be noted

that the orientation of various elements may differ according to other exemplary embodiments, and that such variations are intended to be encompassed by the present disclosure.

(84) The hardware and data processing components used to implement the various processes, operations, illustrative logics, logical blocks, modules and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose single- or multi-chip processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, or, any conventional processor, controller, microcontroller, or state machine. A processor also may be implemented as a combination of computing devices, such as a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration. In some embodiments, particular processes and methods may be performed by circuitry that is specific to a given function. The memory (e.g., memory, memory unit, storage device) may include one or more devices (e.g., RAM, ROM, Flash memory, hard disk storage) for storing data and/or computer code for completing or facilitating the various processes, layers and modules described in the present disclosure. The memory may be or include volatile memory or non-volatile memory, and may include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures described in the present disclosure. According to an exemplary embodiment, the memory is communicably connected to the processor via a processing circuit and includes computer code for executing (e.g., by the processing circuit or the processor) the one or more processes described herein.

(85) The present disclosure contemplates methods, systems and program products on any machine-readable media for accomplishing various operations. The embodiments of the present disclosure may be implemented using existing computer processors, or by a special purpose computer processor for an appropriate system, incorporated for this or another purpose, or by a hardwired system. Embodiments within the scope of the present disclosure include program products comprising machine-readable media for carrying or having machine-executable instructions or data structures stored thereon. Such machine-readable media can be any available media that can be accessed by a general purpose or special purpose computer or other machine with a processor. By way of example, such machine-readable media can comprise RAM, ROM, EPROM, EEPROM, or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to carry or store desired program code in the form of machine-executable instructions or data structures and which can be accessed by a general purpose or special purpose computer or other machine with a processor. Combinations of the above are also included within the scope of machine-readable media. Machine-executable instructions include, for example, instructions and data which cause a general purpose computer, special purpose computer, or special purpose processing machines to perform a certain function or group of functions.

(86) Although the figures and description may illustrate a specific order of method steps, the order of such steps may differ from what is depicted and described, unless specified differently above. Also, two or more steps may be performed concurrently or with partial concurrence, unless specified differently above. Such variation may depend, for example, on the software and hardware systems chosen and on designer choice. All such variations are within the scope of the disclosure. Likewise, software implementations of the described methods could be accomplished with standard programming techniques with rule-based logic and other logic to accomplish the various connection steps, processing steps, comparison steps, and decision steps.

(87) It is important to note that the construction and arrangement of the refuse vehicle **10** and the systems and components thereof as shown in the various exemplary embodiments is illustrative only. Additionally, any element disclosed in one embodiment may be incorporated or utilized with

any other embodiment disclosed herein. Although only one example of an element from one embodiment that can be incorporated or utilized in another embodiment has been described above, it should be appreciated that other elements of the various embodiments may be incorporated or utilized with any of the other embodiments disclosed herein.

Claims

1. A refuse vehicle, comprising: a prime mover configured to drive tractive elements of the refuse vehicle; a plurality of accessories configured to consume electrical energy; a battery configured to provide electrical energy for the plurality of accessories; and processing circuitry configured to limit operation of at least one of the plurality of accessories based on a state of charge of the battery to extend a transportation range of the refuse vehicle.
2. The refuse vehicle of claim 1, wherein the refuse vehicle is a fully electric refuse vehicle and the prime mover an electric motor configured to consume electrical energy provided by the battery to drive one or more of the tractive elements for transportation of the refuse vehicle.
3. The refuse vehicle of claim 1, wherein the processing circuitry is configured to limit operation of at least one of the plurality of accessories in response to the state of charge of the battery decreasing below a threshold value, wherein limiting operation of at least one of the plurality of accessories conserves energy discharge of the battery and extends the transportation range of the refuse vehicle.
4. The refuse vehicle of claim 1, further comprising a supplemental energy source, wherein the processing circuitry is configured to activate the supplemental energy source to charge the battery in response to the state of charge of the battery or to provide supplemental energy to the prime mover.
5. The refuse vehicle of claim 4, wherein the supplemental energy source is any of: an additional battery pack; a fuel cell; or an accessory power unit, comprising: a plurality of tanks configured to store a fuel; a generator configured to be driven to generate electrical energy to charge the battery; and an engine configured to consume the fuel and drive the generator.
6. The refuse vehicle of claim 5, wherein the fuel stored by the plurality of tanks is a compressed natural gas (CNG) and the engine is a CNG engine configured to consume the CNG to drive the generator.
7. The refuse vehicle of claim 1, further comprising a global positioning system (GPS) configured to provide a current geographical position of the refuse vehicle to the processing circuitry, wherein the processing circuitry is further configured to: determine an amount of energy required for the refuse vehicle to complete a collection route; and limit operation of at least one of the plurality of accessories in response to the state of charge of the battery indicating that the battery is currently insufficient to provide the amount of energy required.
8. The refuse vehicle of claim 1, wherein limiting operation of at least one of the plurality of accessories comprises at least one of: restricting operation of a body function of the refuse vehicle; causing subsequently performed operations of the body function of the refuse vehicle to be performed less frequently; or shutting off power to the body function of the refuse vehicle.
9. A range extension system for a refuse vehicle, comprising: a battery configured to provide electrical energy for a refuse accessory of the refuse vehicle; and processing circuitry, configured to: limit operation of the refuse accessory based on a state of charge of the battery to extend a transportation range of the refuse vehicle.
10. The range extension system of claim 9, wherein the refuse vehicle is a fully electric refuse vehicle and a prime mover of the refuse vehicle is an electric motor configured to consume electrical energy provided by the battery to drive one or more tractive elements for transportation of the refuse vehicle.
11. The range extension system of claim 9, wherein the processing circuitry is configured to limit

operation of the refuse accessory in response to the state of charge of the battery decreasing below a threshold value, wherein limiting operation of the refuse accessory conserves energy discharge of the battery and extends the transportation range of the refuse vehicle.
12. The range extension system of claim 9, further comprising a supplemental energy source, wherein the processing circuitry is configured to activate the supplemental energy source to charge the battery in response to the state of charge of the battery or to provide supplemental energy to a prime mover of the refuse vehicle.
13. The range extension system of claim 12, wherein the supplemental energy source is any of: an additional battery pack; a fuel cell; or an accessory power unit comprising: a plurality of tanks configured to store a fuel; a generator configured to be driven to generate electrical energy to charge the battery; and an engine configured to consume the fuel and drive the generator.
14. The range extension system of claim 13, wherein the fuel stored by the plurality of tanks is a compressed natural gas (CNG) and the engine is a CNG engine configured to consume the CNG to drive the generator.
15. The range extension system of claim 9, further comprising a global positioning system (GPS) configured to provide a current geographical position of the refuse vehicle to the processing circuitry, wherein the processing circuitry is further configured to: determine an amount of energy required for the refuse vehicle to complete a collection route; and limit operation of at least one of the refuse accessory in response to the state of charge of the battery indicating that the battery is currently insufficient to provide the amount of energy required.
16. The range extension system of claim 9, wherein limiting operation of the refuse accessory comprises any of: restricting operation of a body function of the refuse vehicle; reducing a frequency at which operations of the body function are performed; or shutting off power to the body function of the refuse vehicle.
17. A method, comprising: operating an accessory of a refuse vehicle using energy provided by an electrical storage system (ESS); in response to a comparison between a state of charge of the ESS and a threshold indicating insufficient energy to transport the refuse vehicle to a location, at least one of: limiting operation of the accessory of the refuse vehicle; or activating a supplemental energy source to charge the ESS; wherein limiting operation of the accessory of the refuse vehicle or activating the supplemental energy source increases a transportation range of the refuse vehicle; in response to the comparison between the state of charge of the ESS and the threshold indicating sufficient energy to transport the refuse vehicle to the location: continuing to operate the accessory of the refuse vehicle using energy provided by the ESS without limiting operation the accessory and without activating the supplemental energy source.
18. The method of claim 17, wherein the supplemental energy source is any of: an additional battery pack; a fuel cell; or an accessory power unit comprising: a plurality of tanks configured to store a fuel; a generator configured to be driven to generate electrical energy to charge the ESS; and an engine configured to consume the fuel and drive the generator.
19. The method of claim 18, wherein the fuel stored by the plurality of tanks is a compressed natural gas (CNG) and the engine is a CNG engine configured to consume the CNG to drive the generator.
20. The method of claim 17, wherein limiting operation of the accessory comprises any of: restricting operation of a body function of the refuse vehicle; reducing a frequency at which operation of the body function are performed; or shutting off power to the body function of the refuse vehicle.