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(54) **ELECTRIFIED FIRE FIGHTING VEHICLE SYSTEM**

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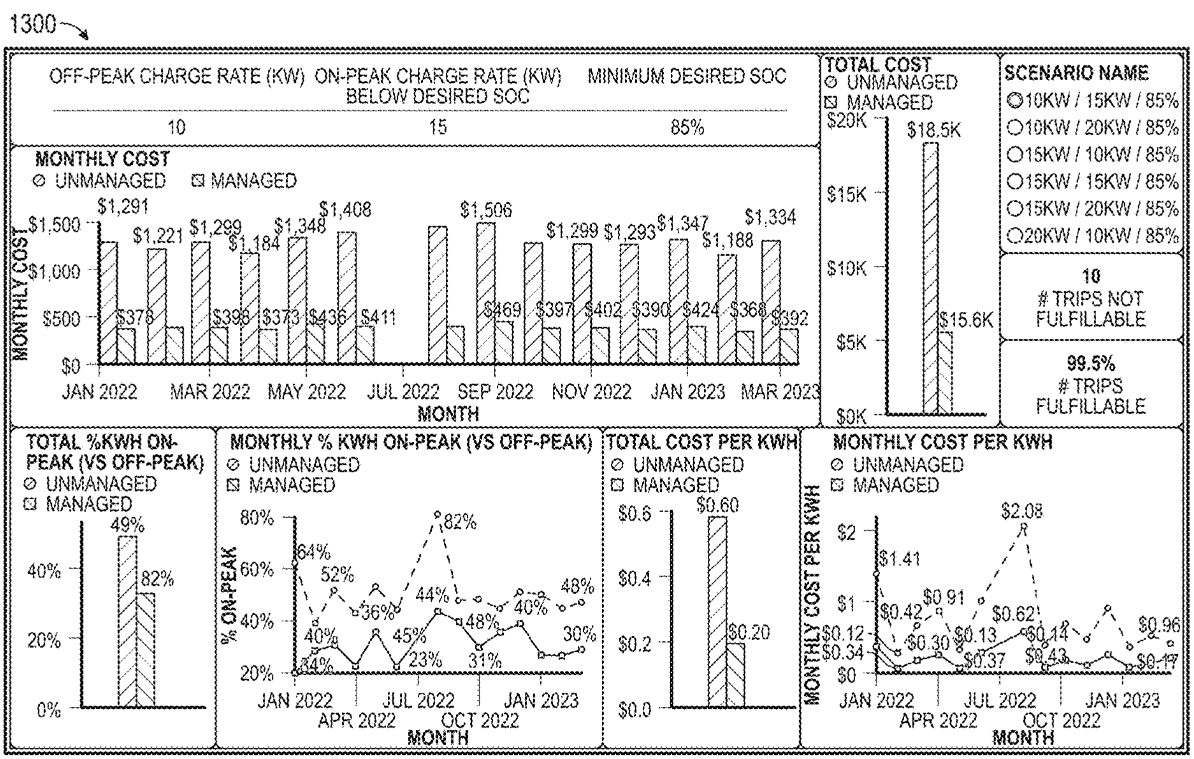
CPC *G06Q 30/0284* (2013.01); *G06Q 50/06* (2013.01)

(57) **ABSTRACT**

An electrified fire apparatus system includes a non-transitory computer-readable medium having instructions stored thereon. The instructions, when executed by one or more processors, cause the one or more processors to acquire first information regarding at least one of average response parameters or response requirements for a respective fire department, acquire second information regarding a respective electrified fire apparatus that the respective fire department owns or is considering purchasing, and provide at least one of (a) a recommendation for a size of a charger based on the first information and the second information or (b) a recovery time output based on the first information, the second information, and the size of the charger. The recovery time output includes a value indicating an amount of time it would take to recover energy depleted from the respective electrified fire apparatus following an average call for the respective fire department based on the size.



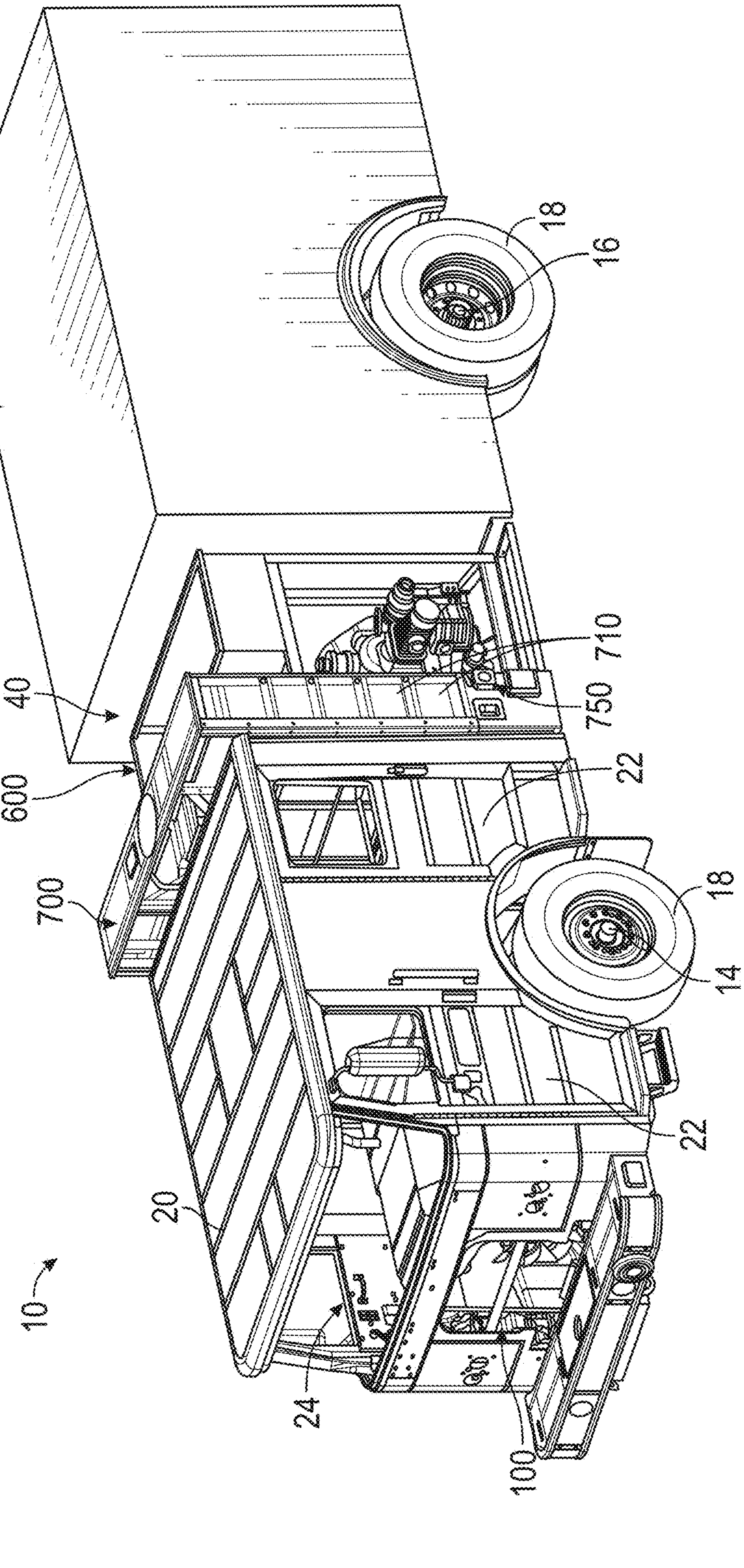


FIG. 1A

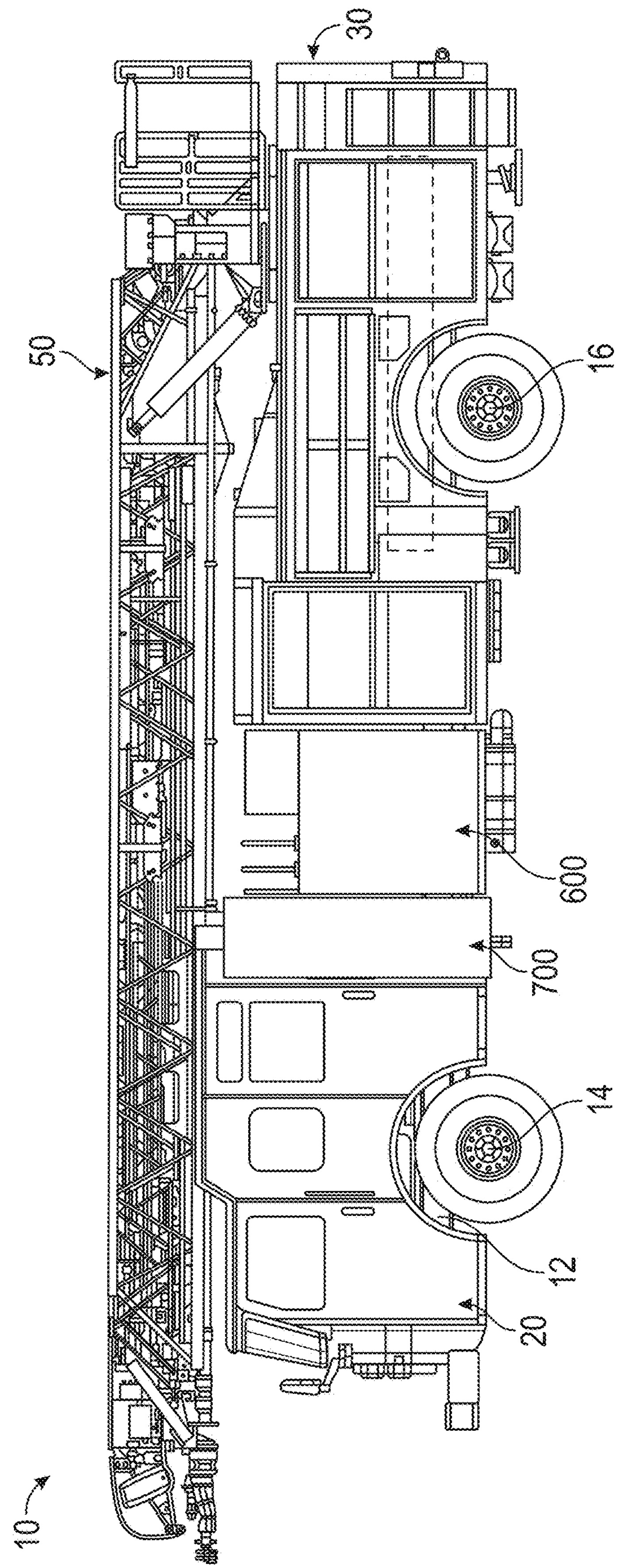


FIG. 1B

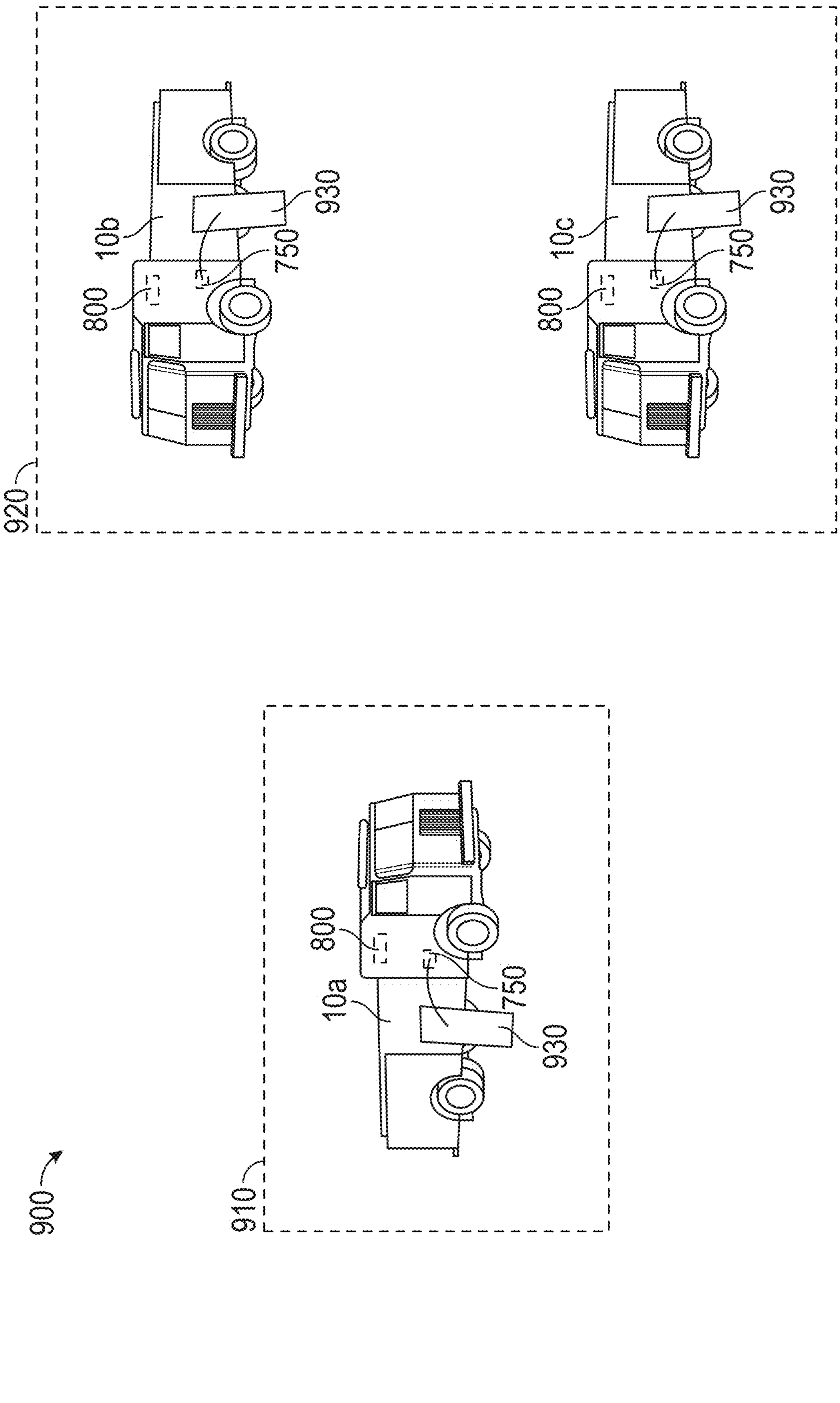


FIG. 2

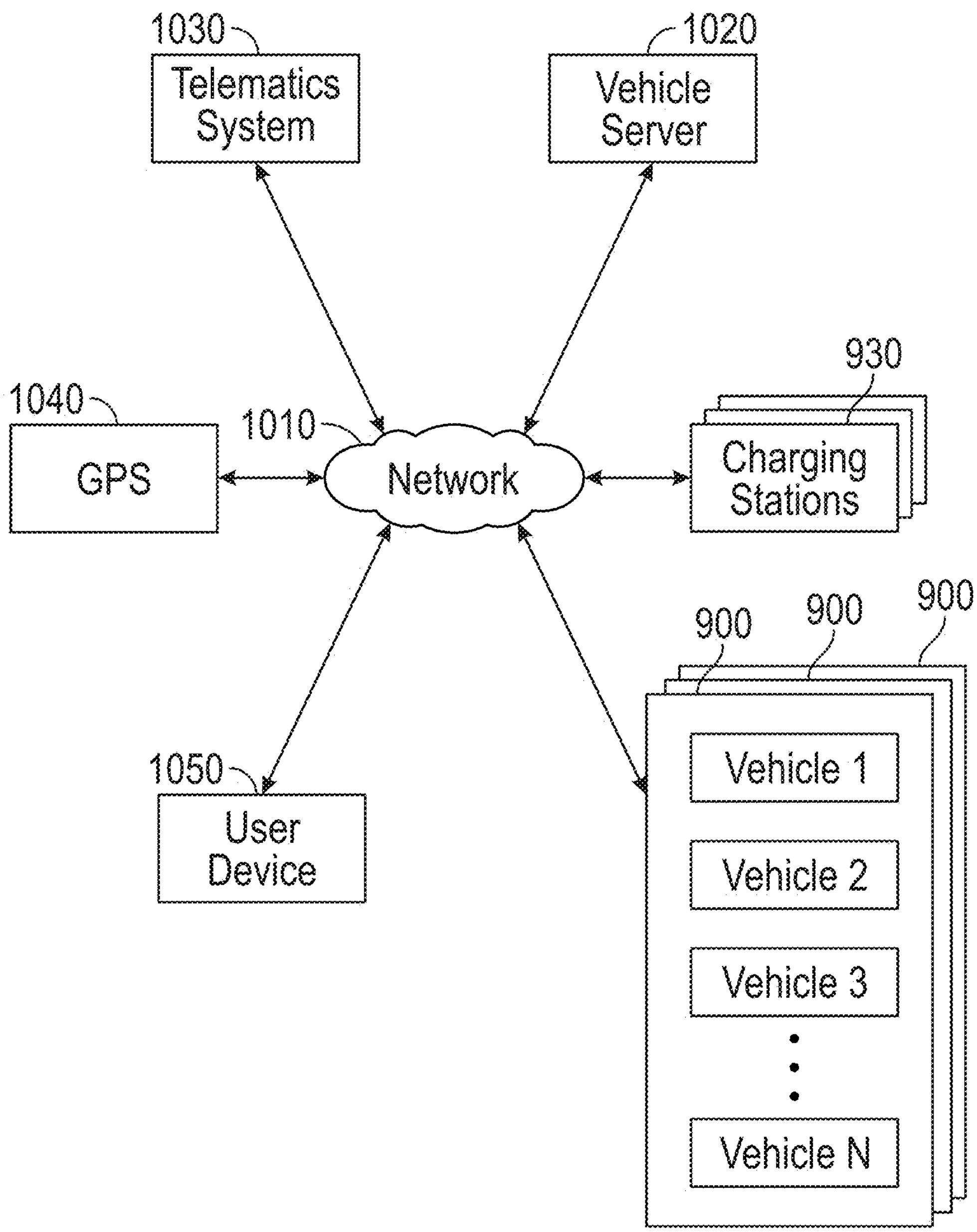

1030
Telematics System
1020
Vehicle Server
1040
GPS
1010
Network
930
Charging Stations
900
900
900
Vehicle 1
Vehicle 2
Vehicle 3
Vehicle N
1050
User Device

FIG. 3

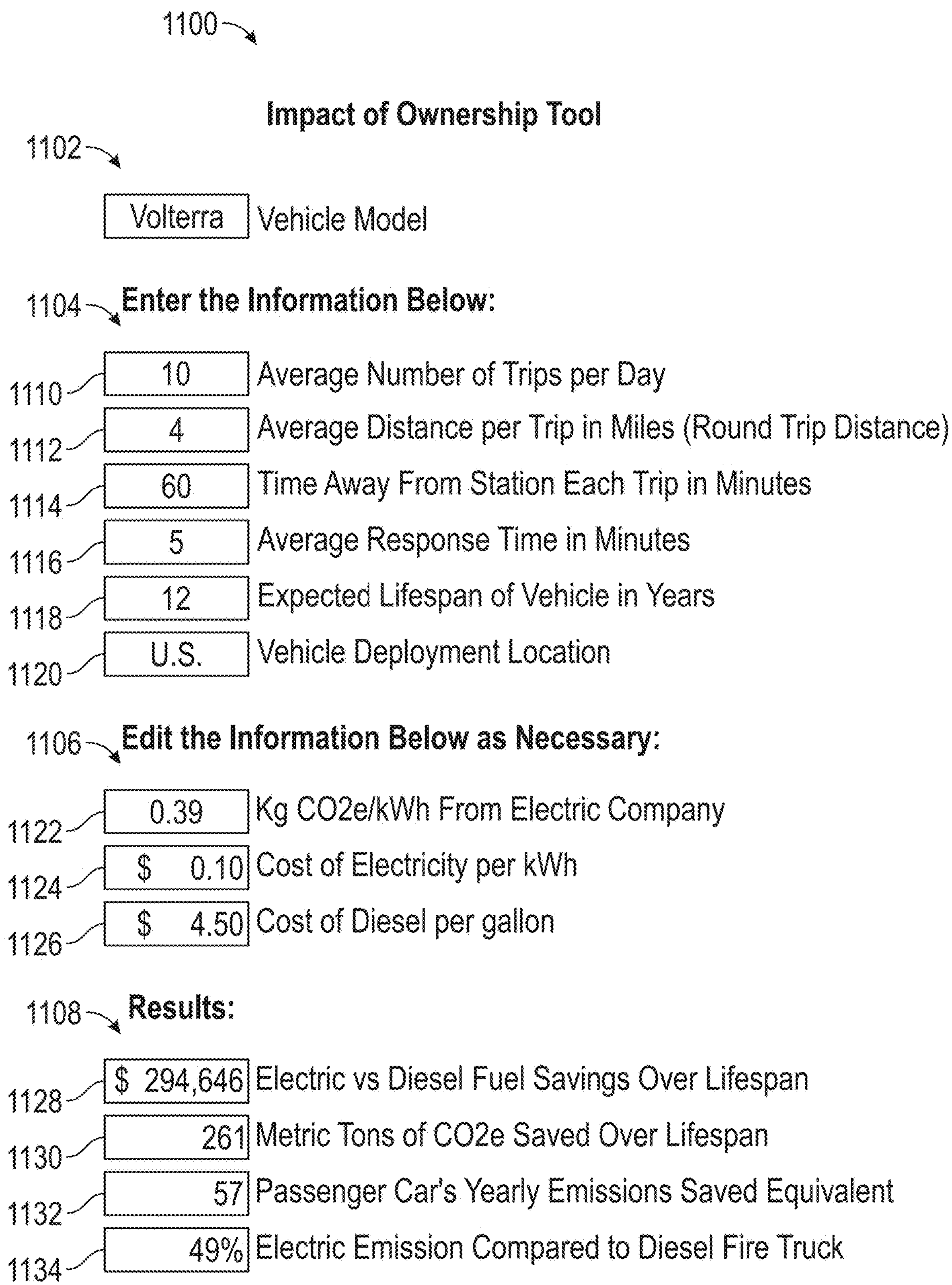

1100
Impact of Ownership Tool
1102
Volterra Vehicle Model
1104 Enter the Information Below:
1110 10 Average Number of Trips per Day
1112 4 Average Distance per Trip in Miles (Round Trip Distance)
1114 60 Time Away From Station Each Trip in Minutes
1116 5 Average Response Time in Minutes
1118 12 Expected Lifespan of Vehicle in Years
1120 U.S. Vehicle Deployment Location
1106 Edit the Information Below as Necessary:
1122 0.39 Kg CO2e/kWh From Electric Company
1124 $ 0.10 Cost of Electricity per kWh
1126 $ 4.50 Cost of Diesel per gallon
1108 Results:
1128 $ 294,646 Electric vs Diesel Fuel Savings Over Lifespan
1130 261 Metric Tons of CO2e Saved Over Lifespan
1132 57 Passenger Car's Yearly Emissions Saved Equivalent
1134 49% Electric Emission Compared to Diesel Fire Truck

FIG. 4

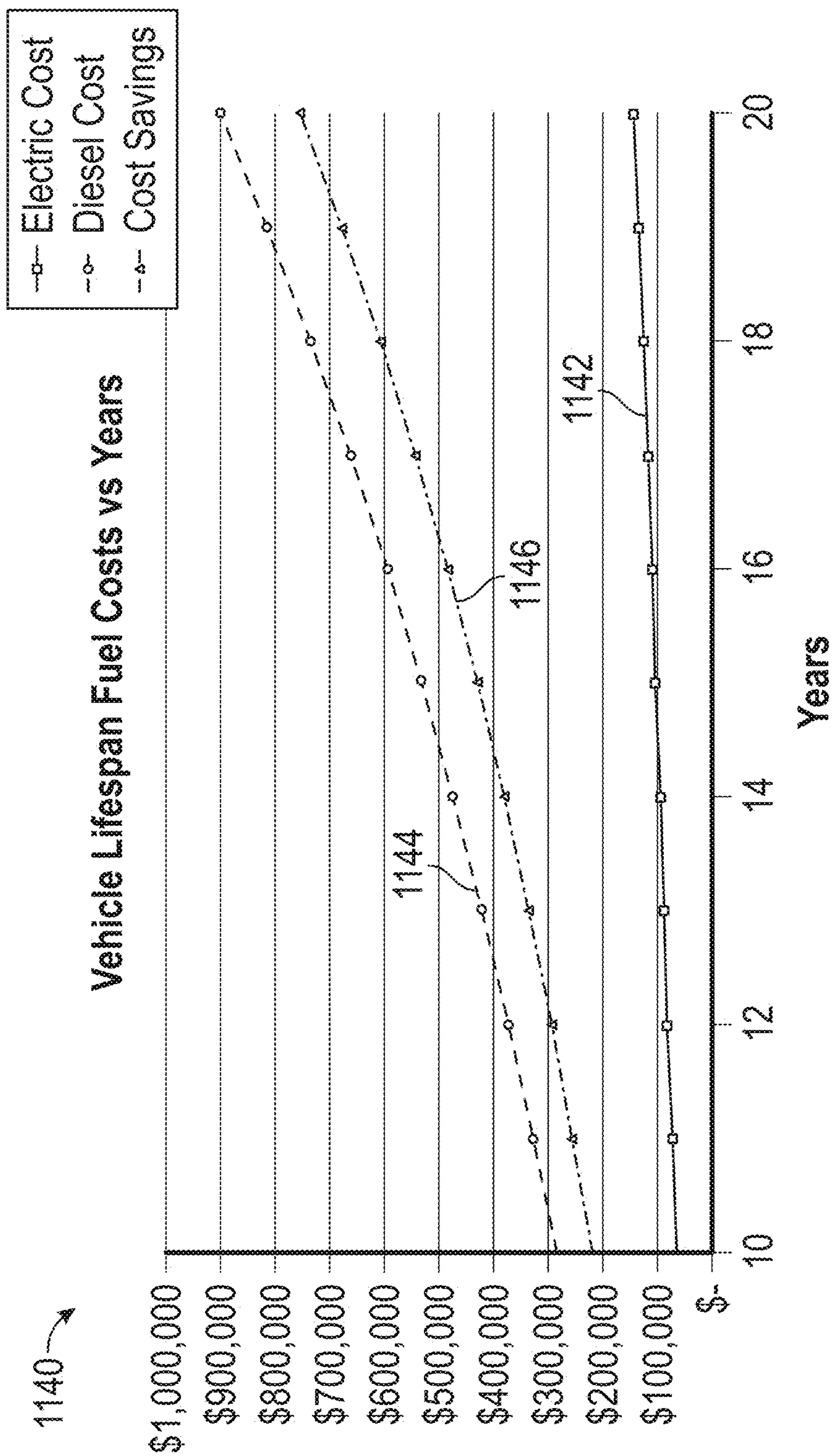

1140
Vehicle Lifespan Fuel Costs vs Years
Electric Cost
Diesel Cost
Cost Savings
$1,000,000
$900,000
$800,000
$700,000
$600,000
$500,000
$400,000
$300,000
$200,000
$100,000
$-
10
12
14
16
18
20
Years
1142
1144
1146

FIG. 5

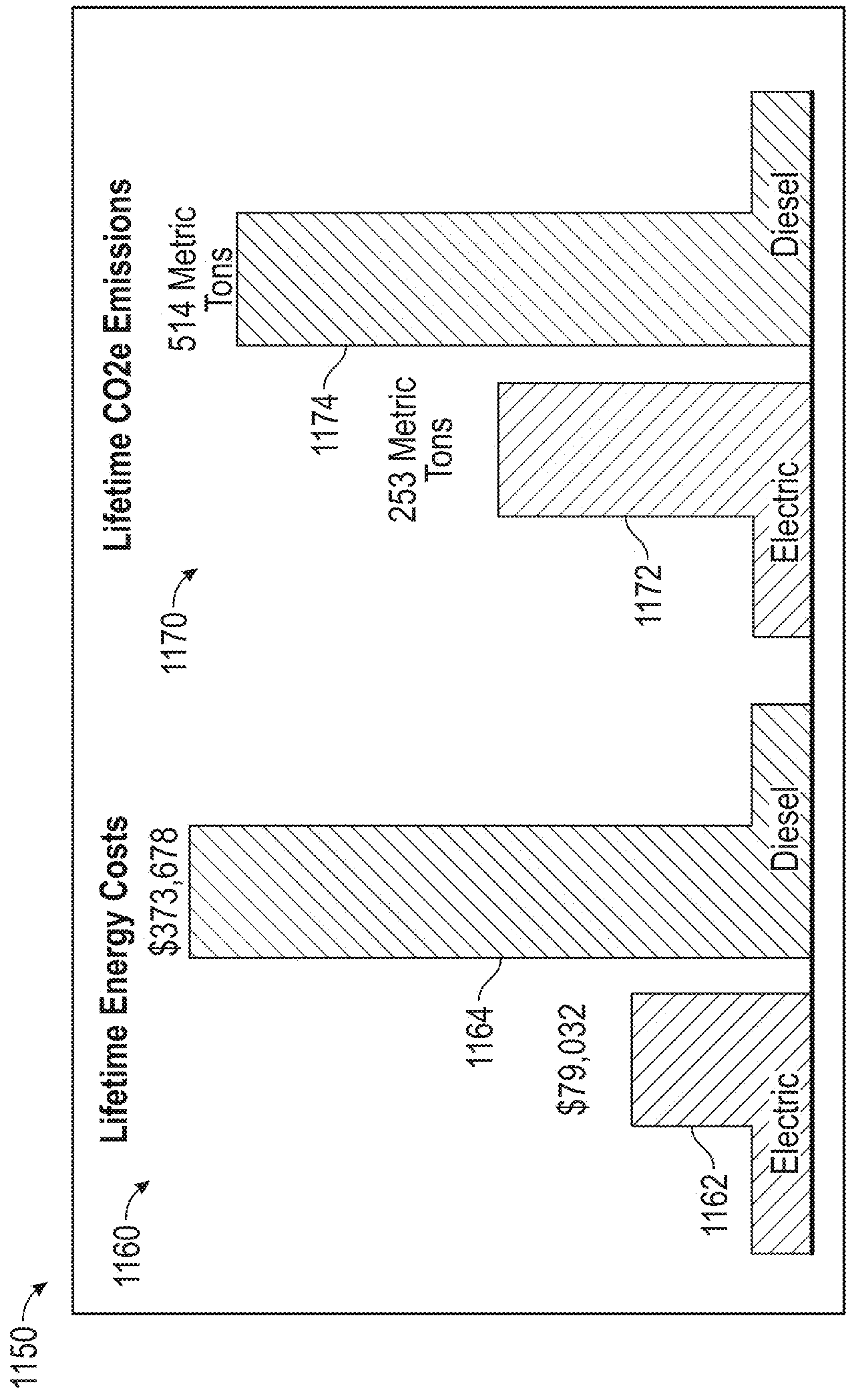

1150
1160
Lifetime Energy Costs
$373,678
1164
$79,032
1162
Electric
Diesel
1170
Lifetime CO2e Emissions
514 Metric Tons
1174
253 Metric Tons
1172
Electric
Diesel

FIG. 6

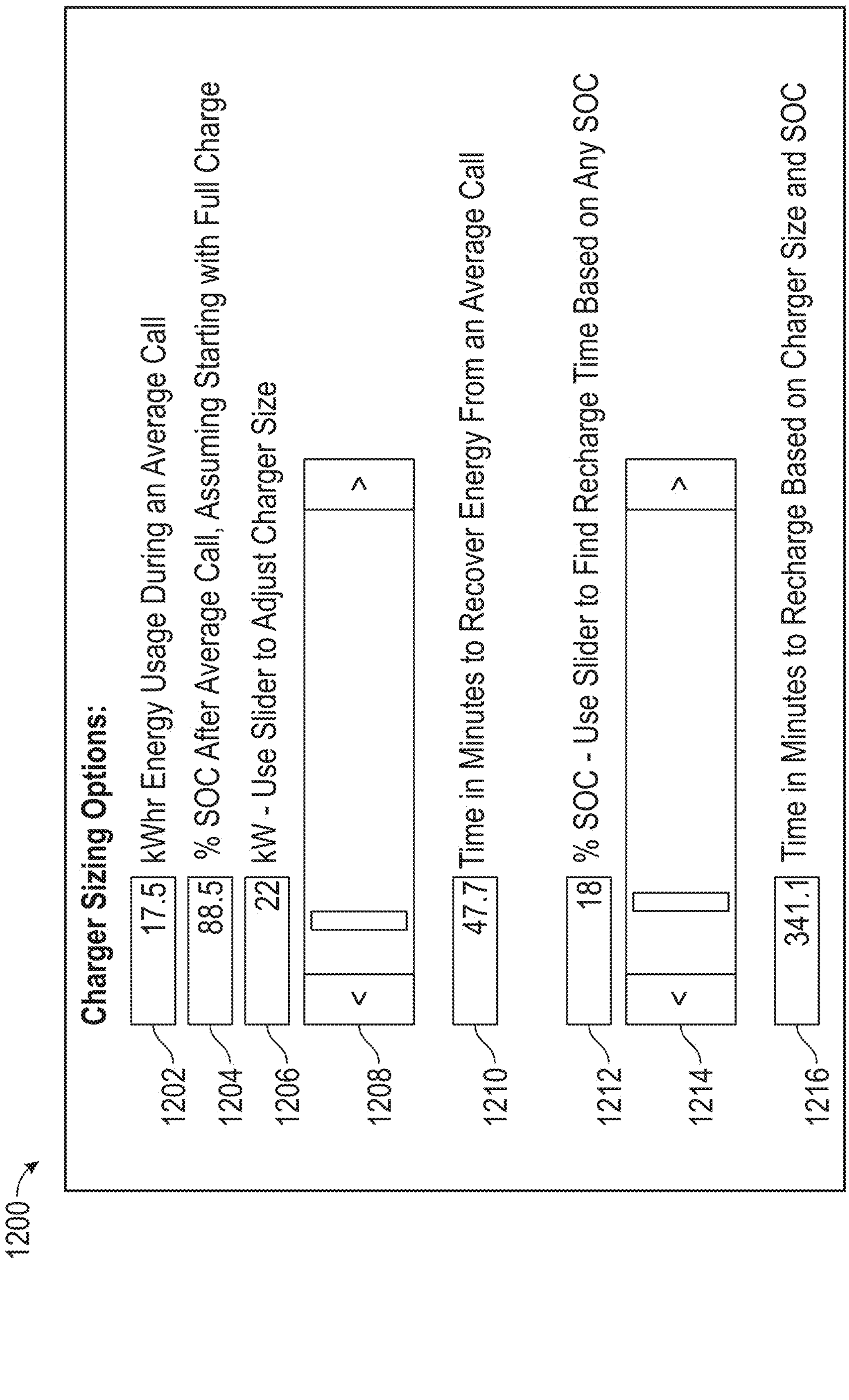

1200
Charger Sizing Options:
1202
17.5
kWhr Energy Usage During an Average Call
1204
88.5
% SOC After Average Call, Assuming Starting with Full Charge
1206
22
kW - Use Slider to Adjust Charger Size
1208
<
>
1210
47.7
Time in Minutes to Recover Energy From an Average Call
1212
18
% SOC - Use Slider to Find Recharge Time Based on Any SOC
1214
<
>
1216
341.1
Time in Minutes to Recharge Based on Charger Size and SOC

FIG. 7

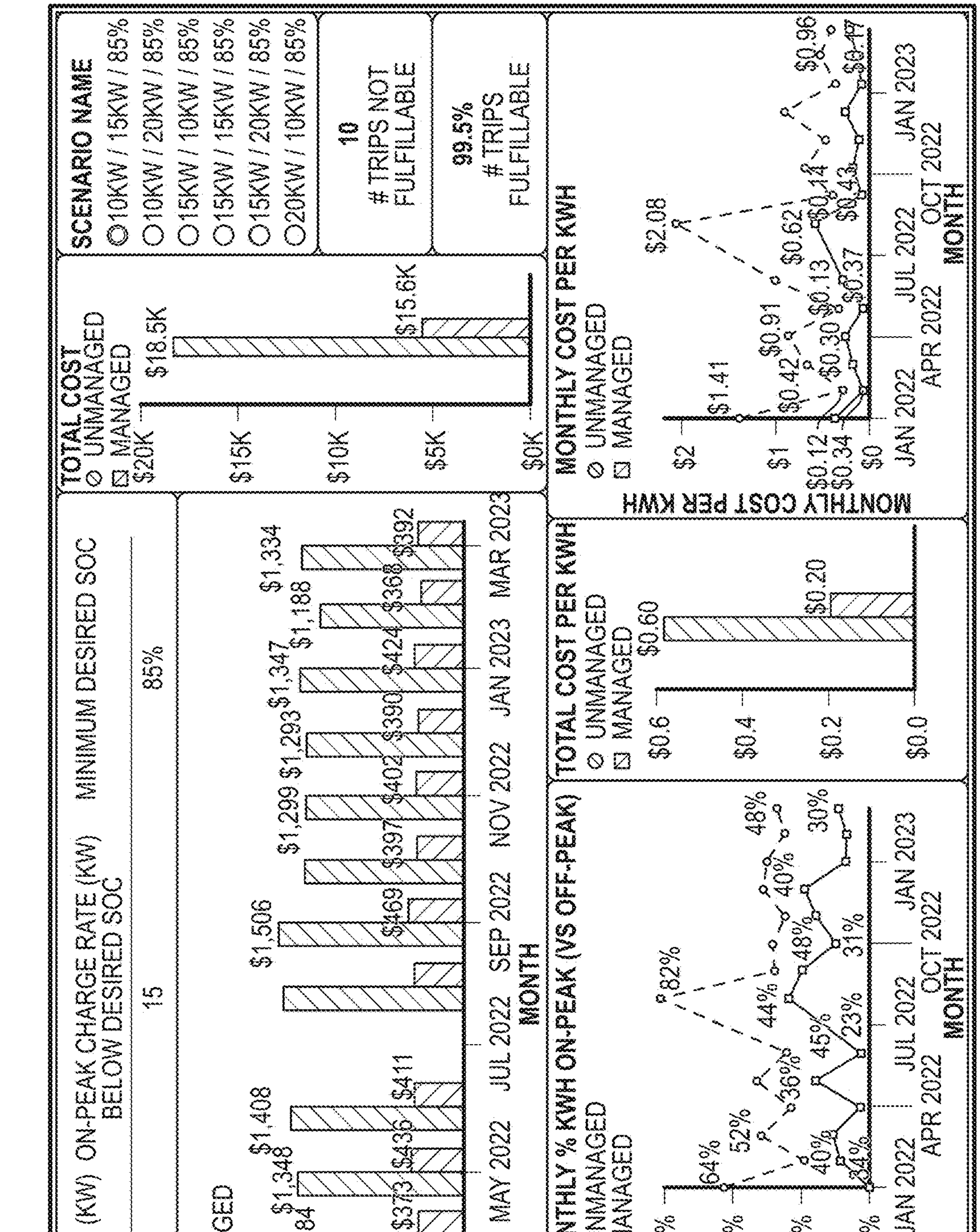

1300
OFF-PEAK CHARGE RATE (KW)
ON-PEAK CHARGE RATE (KW) BELOW DESIRED SOC
MINIMUM DESIRED SOC
10
15
85%
TOTAL COST
UNMANAGED
MANAGED
$18.5K
$15.6K
SCENARIO NAME
10KW / 15KW / 85%
10KW / 20KW / 85%
15KW / 10KW / 85%
15KW / 15KW / 85%
15KW / 20KW / 85%
20KW / 10KW / 85%
10
TRIPS NOT FULFILLABLE
99.5%
TRIPS FULFILLABLE
MONTHLY COST
UNMANAGED
MANAGED
MONTHLY COST
MONTH
TOTAL %KWH ON-PEAK (VS OFF-PEAK)
UNMANAGED
MANAGED
49%
82%
MONTHLY % KWH ON-PEAK (VS OFF-PEAK)
UNMANAGED
MANAGED
% ON-PEAK
MONTH
TOTAL COST PER KWH
UNMANAGED
MANAGED
$0.60
$0.20
MONTHLY COST PER KWH
UNMANAGED
MANAGED
MONTHLY COST PER KWH
MONTH

FIG. 8

ELECTRIFIED FIRE FIGHTING VEHICLE SYSTEM

CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

[0001] This application claims the benefit of and priority to U.S. Provisional Patent Application No. 63/551,940, filed Feb. 9, 2024, which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Costs associated with charging electrified vehicles can shift drastically throughout the day based on demand on the power grid. If an electrified vehicle is plugged in at peak hours, it can cost significantly more to charge the electrified vehicle than at off or non-peak hours.

SUMMARY

[0003] One embodiment relates to an electrified fire apparatus system. The electrified fire apparatus system includes one or more processing circuits including one or more memory devices coupled to one or more processors. The one or more memory devices are configured to store instructions thereon that, when executed by the one or more processors, cause the one or more processors to acquire first information regarding (a) at least one of average response parameters or response requirements for a respective fire department and (b) a location of the respective fire department, acquire second information regarding at least one of average costs or environmental impacts for operating one or more fire apparatuses associated with the respective department, and provide a results graphical user interface for display providing one or more results for a respective electrified fire apparatus based on the first information and the second information. The one or more results include at least one of: (a) an energy cost savings output providing a projected energy cost savings over a lifespan of the respective electrified fire apparatus by owning and operating the respective electrified fire apparatus rather than an equivalent internal combustion engine (ICE) variant thereof, (b) a CO_2e savings output providing a projected CO_2e emissions savings over the lifespan of the respective electrified fire apparatus by owning and operating the respective electrified fire apparatus rather than the equivalent ICE variant, or (c) an emissions output providing a projected amount or percentage of emission generated by the respective electrified fire apparatus over the lifespan of the respective electrified fire apparatus relative to the equivalent ICE variant.

[0004] Another embodiment relates to an electrified fire apparatus system. The electrified fire apparatus system includes a non-transitory computer-readable medium having instructions stored thereon. The instructions, when executed by one or more processors, cause the one or more processors to acquire first information regarding (a) at least one of average response parameters or response requirements for a respective fire department and (b) a location of the respective fire department, acquire second information regarding at least one of average costs or environmental impacts for operating one or more fire apparatuses associated with the respective department, and provide a results graphical user interface for display providing one or more results for a respective electrified fire apparatus based on the first information and the second information. The one or more results include at least one of: (a) an energy cost savings output providing a projected energy cost savings over a lifespan of the respective electrified fire apparatus by owning and operating the respective electrified fire apparatus rather than an equivalent internal combustion engine (ICE) variant thereof, (b) a CO_2e savings output providing a projected CO_2e emissions savings over the lifespan of the respective electrified fire apparatus by owning and operating the respective electrified fire apparatus rather than the equivalent ICE variant, or (c) an emissions output providing a projected amount or percentage of emission generated by the respective electrified fire apparatus over the lifespan of the respective electrified fire apparatus relative to the equivalent ICE variant.

[0005] Still another embodiment relates to an electrified fire apparatus system. The electrified fire apparatus system includes a non-transitory computer-readable medium having instructions stored thereon. The instructions, when executed by one or more processors, cause the one or more processors to acquire first information regarding at least one of average response parameters or response requirements for a respective fire department, acquire second information regarding a respective electrified fire apparatus that the respective fire department owns or is considering purchasing, and provide at least one of (a) a recommendation for a size of a charger based on the first information and the second information or (b) a recovery time output based on the first information, the second information, and the size of the charger. The recovery time output includes a value indicating an amount of time it would take to recover energy depleted from the respective electrified fire apparatus following an average call for the respective fire department based on the size of the charger.

[0006] 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.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1**A is a front, left perspective view of an electrified fire fighting vehicle, according to an exemplary embodiment.

[0008] FIG. **1**B is a side view of the electrified fire fighting vehicle of FIG. **1**A with an aerial ladder assembly, according to an exemplary embodiment.

[0009] FIG. **2** is a schematic block diagram of a fleet of electrified fire fighting vehicles, according to an exemplary embodiment.

[0010] FIG. **3** is a schematic diagram of a control system for the fleet of electrified fire fighting vehicles of FIG. **2**, according to an exemplary embodiment.

[0011] FIG. **4** is a graphical user interface displaying an impact of ownership tool, according to an exemplary embodiment.

[0012] FIG. **5** is a first graph output by the impact of ownership tool of FIG. **4** showing energy costs over time, according to an exemplary embodiment.

[0013] FIG. **6** is a second graph output by the impact of ownership tool of FIG. **4** showing lifetime energy costs and CO_2e emissions, according to an exemplary embodiment.

[0014] FIG. **7** is a graphical user interface displaying a charger sizing tool, according to an exemplary embodiment.

[0015] FIG. **8** is a graphical user interface displaying a charge management tool, according to an exemplary embodiment.

DETAILED DESCRIPTION

[0016] 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.

Vehicle

[0017] According to the exemplary embodiment shown in FIGS. **1**A and **1**B, a machine, shown vehicle **10**, is configured as a fire fighting vehicle. In the embodiment shown in FIG. **1**A, the fire fighting vehicle is a pumper fire truck. In the embodiment shown in FIG. **1**B, the fire fighting vehicle is an aerial ladder truck. The aerial ladder truck may include a rear-mount aerial ladder or a mid-mount aerial ladder. In some embodiments, the aerial ladder truck is a quint fire truck. In other embodiments, the aerial ladder truck is a tiller fire truck. In still another embodiment, the fire fighting vehicle is an airport rescue fire fighting ("ARFF") truck. In various embodiments, the fire fighting vehicle (e.g., a quint, a pumper, a tanker, an ARFF, etc.) includes an on-board water storage tank, an on-board agent storage tank, and/or a pumping system. In other embodiments, the fire fighting vehicle is still another type of fire fighting vehicle. In an alternative embodiment, the vehicle **10** is another type of vehicle other than a fire fighting vehicle. For example, the vehicle **10** may be a refuse truck, a concrete mixer truck, a military vehicle, a tow truck, an ambulance, a farming/agriculture machine or vehicle, a construction machine or vehicle, airport ground service equipment (e.g., a tractor, a loader, a de-icer truck, etc.), and/or still another vehicle or machine.

[0018] As shown in FIGS. **1**A and **1**B, the vehicle **10** includes a chassis, shown as frame **12**; a plurality of axles, shown as front axle **14** and rear axle **16**, supported by the frame **12** and that couple a plurality of tractive elements, shown as wheels **18**, to the frame **12**; a cab, shown as front cabin **20**, supported by the frame **12**; a body assembly, shown as a rear section **30**, supported by the frame **12** and positioned rearward of the front cabin **20**; and a driveline (e.g., a powertrain, a drivetrain, an accessory drive, a prime mover, an electric driveline including one or more motors, a hybrid driveline including an engine and one or more motors, a non-hybrid, dual-drive driveline including an engine and one or more motors etc.), shown as driveline **100**. While shown as including a single front axle **14** and a single rear axle **16**, in other embodiments, the vehicle **10** includes two front axles **14** and/or two rear axles **16**. In an alternative embodiment, the tractive elements are otherwise structured (e.g., tracks, etc.).

[0019] According to an exemplary embodiment, the front cabin **20** includes a plurality of body panels coupled to a support (e.g., a structural frame assembly, etc.). The body panels may define a plurality of openings through which an operator accesses an interior **24** of the front cabin **20** (e.g., for ingress, for egress, to retrieve components from within, etc.). As shown in FIGS. **1**A and **1**B, the front cabin **20** includes a plurality of doors, shown as doors **22**, positioned over the plurality of openings defined by the plurality of body panels. The doors **22** may provide access to the interior **24** of the front cabin **20** for a driver and/or passengers of the vehicle **10**. The doors **22** may be hinged, sliding, or bus-style folding doors.

[0020] The front cabin **20** may include components arranged in various configurations. Such configurations may vary based on the particular application of the vehicle **10**, customer requirements, or still other factors. The front cabin **20** may be configured to contain or otherwise support a number of occupants, storage units, and/or equipment. For example, the front cabin **20** may provide seating for an operator (e.g., a driver, etc.) and/or one or more passengers of the vehicle **10**. The front cabin **20** may include one or more storage areas for providing compartmental storage for various articles (e.g., supplies, instrumentation, equipment, etc.). The interior **24** of the front cabin **20** may further include a user interface. The user interface may include a cabin display and various controls (e.g., buttons, switches, knobs, levers, joysticks, etc.). In some embodiments, the user interface within the interior **24** of the front cabin **20** further includes touchscreens, a steering wheel, an accelerator pedal, and/or a brake pedal, among other components. The user interface may provide the operator with control capabilities over the vehicle **10** (e.g., direction of travel, speed, etc.), one or more components of driveline **100**, and/or still other components of the vehicle **10** from within the front cabin **20**.

[0021] In some embodiments, the rear section **30** includes a plurality of compartments with corresponding doors positioned along one or more sides (e.g., a left side, right side, etc.) and/or a rear of the rear section **30**. The plurality of compartments may facilitate storing various equipment such as oxygen tanks, hoses, axes, extinguishers, ladders, chains, ropes, straps, boots, jackets, blankets, first-aid kits, and/or still other equipment. One or more of the plurality of compartments may include various storage apparatuses (e.g., shelving, hooks, racks, etc.) for storing and organizing the equipment.

[0022] In some embodiments (e.g., when the vehicle **10** is an aerial ladder truck, etc.), as shown in FIG. **1**B, the rear section **30** includes an aerial ladder assembly, shown as aerial ladder **50**. The aerial ladder **50** may have a fixed length or may have one or more extensible ladder sections. The aerial ladder **50** may include a basket or implement (e.g., a water turret, etc.) coupled to a distal or free end thereof. According to the exemplary embodiment shown in FIG. **1**B, the aerial ladder **50** is coupled to the frame **12** proximate a rear of the rear section **30** (e.g., a rear-mount fire truck). In some embodiments, the aerial ladder **50** is coupled to the frame **12** proximate a front of the rear section **30** (e.g., a mid-mount fire truck).

[0023] In some embodiments (e.g., when the vehicle **10** is an ARFF truck, a pumper truck, a tanker truck, a quint truck, etc.), the rear section **30** includes one or more fluid tanks. By way of example, the one or more fluid tanks may include a water tank and/or an agent tank. The water tank and/or the agent tank may be corrosion and UV resistant polypropylene tanks. In a municipal fire truck implementation (i.e., a non-ARFF truck implementation), the water tank may have a maximum water capacity ranging between 50 and 1000 gallons (e.g., 50, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, 800, 850, 900, 950, 1000, etc. gallons). In an ARRF truck implementation, the water tank may have a maximum water capacity ranging between 1,000 and 4,500 gallons (e.g., at least 1,250 gallons; between 2,500 gallons and 3,500 gallons; at most 4,500 gallons; at most 3,000 gallons; at most 1,500 gallons; etc.). The agent tank may have a maximum agent capacity ranging between 25 and 750 gallons (e.g., 25, 50, 75, 100, 150, 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, etc. gallons). According to an exemplary embodiment, the agent is a foam fire suppressant, an aqueous film forming foam ("AFFF"). A low-expansion foam, a medium-expansion foam, a high-expansion foam, an alcohol-resistant foam, a synthetic foam, a protein-based foams, a fluorine-free foam, a film-forming fluoro protein ("FFFP") foam, an alcohol resistant aqueous film forming foam ("AR-AFFF"), and/or still another suitable foam or a foam yet to be developed. The capacity of the water tank and/or the agent tank may be specified by a customer. It should be understood that water tank and the agent tank configurations are highly customizable, and the scope of the present disclosure is not limited to a particular size or configuration of the water tank and the agent tank.

[0024] According to an exemplary embodiment, the driveline **100** includes one or more electric motors configured to drive the front axle **14** and/or the rear axle **16**. In some embodiments, the driveline **100** includes an engine to supplement the one or more electric motors. Accordingly, the driveline **100** may be an all-electric driveline, a hybrid driveline, and/or a dual-drive driveline.

[0025] As shown in FIGS. **1**A and **1**B, the vehicle **10** includes a pump assembly, shown as pump system **600**, coupled to the frame **12** and positioned between the front cabin **20** and the rear section **30**. In other embodiments, the pump system **60** is otherwise positioned (e.g., within the rear section **30**). As shown in FIGS. **1**A and **1**B, the vehicle **10** includes an on-board energy storage system ("ESS"), shown as ESS **700**, coupled to the frame **12** and positioned between the front cabin **20** and the rear section **30**. In other embodiments, the ESS **700** is otherwise positioned (e.g., within the rear section **30**, under the front cabin **20**, under the rear section **30**, etc.). According to an exemplary embodiment, the ESS **700** is configured to power the one or more electric motors of the driveline **100**. As shown in FIG. **1**A, the ESS **700** includes one or more battery packs, shown as battery packs **710**, and a charging system, shown as high voltage charging system **750**. According to an exemplary embodiment, the high voltage charging system **750** includes a charging port that facilities selectively, electrically coupling the battery packs **710** to an external power source (e.g., a charging station, etc.). Further details regarding the vehicle **10** may be found in U.S. Patent Publication No. 2022/0355141, filed Apr. 26, 2022, U.S. Patent Application No. 2024/0149815, filed Nov. 3, 2023, both of which are incorporated herein by reference in their entireties.

Vehicle Fleet

[0026] As shown in FIGS. **2** and **3**, a fleet, shown as vehicle fleet **900**, includes a plurality of vehicles, shown as vehicle **10***a*, vehicle **10***b*, vehicle **10***c*, . . . , and vehicle **10***n*. The vehicle **10***a*, the vehicle **10***b*, the vehicle **10***c*, . . . , and the vehicle **10***n* may be the same or similar to the vehicle **10**. Accordingly, the vehicles **10**, as used herein, may refer to the vehicle **10***a*, the vehicle **10***b*, the vehicle **10***c*, . . . , and the vehicle **10***n*. As shown in FIG. **2**, the vehicles **10** include an on-board control system, shown as vehicle controller **800**.

[0027] According to an exemplary embodiment, the vehicles **10** in the vehicle fleet **900** are associated with a respective fire department. As shown in FIG. **2**, the vehicles **10** of the vehicle fleet **900** are dispersed or distributed between a first location, shown location **910**, and a second location, shown as location **920**. By way of example, the location **910** may be a first fire station (fire station A) that is part of the respective fire department and is associated with or that services a first area or district in a respective city, municipality, county, town, village, etc. and the location **920** may be a second fire station (fire station B) that is part of the respective fire department and is associated with or that services a second area or district in the respective city, municipality, county, town, village, etc. In some embodiments, the vehicles **10** are dispersed or distributed between more than two locations (e.g., in a larger city, county, municipality, etc.). In some embodiments, the vehicles **10** are centrally located at a single location (e.g., in a smaller city, county, municipality, town, village, etc.).

[0028] As shown in FIG. **2**, each of the location **910** and the location **920** includes one or more external power sources, shown as charging stations **930**. According to an exemplary embodiment, the charging stations **930** are configured to electrically couple to the ESS **700** of the vehicles **10** via the high voltage charging system **750** of the ESS **700** to facilitate charging the battery packs **710** of the ESS **700**.

Vehicle Evaluation, Charging, and Optimization System

[0029] As shown in FIG. **3**, a vehicle system, shown as vehicle evaluation, charging, and optimization system **1000**, includes one or more vehicle fleets **900**, one or more charging stations **930**, a network (e.g., the Internet, etc.), shown as network **1010**, a remote server, shown as vehicle server **1020**, a first external system, shown as telematics system **1030**, a second external system, shown as global positioning system ("GPS") **1040**, and a user access device, shown user device **1050**.

[0030] According to the exemplary embodiment, the vehicle controllers **800** and/or the vehicle server **1020** are 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. According to the exemplary embodiment, the vehicle controllers **800** and/or the vehicle server **1020** include a processing circuit and a memory. The processing circuit 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. In some embodiments, the processing circuit is configured to execute computer code stored in the memory to facilitate the activities described herein. The memory 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, the memory includes computer code modules (e.g., executable code, object code, source code, script code, machine code, etc.) configured for execution by the processing circuit. In some embodiments, the vehicle controllers **800** and/or the vehicle server **1020** represent a collection of processing devices. In such cases, the processing circuit represents the collective processors of the devices, and the memory represents the collective storage devices of the devices.

[0031] The telematics system **1030** may be a server-based system that monitors various telematics information and provides telematics data based on the telematics information to the vehicle server **1020** and/or the vehicle controllers **800** over the network **1010**. The GPS **1040** may similarly be a server-based system that monitors various GPS information and provides GPS data based on the GPS information to the vehicle server **1020** and/or the vehicle controllers **800** over the network **1010**. In some embodiments, the telematics system **1030** and the GPS **1040** are integrated into a single system. The telematics data may include electricity costs at each of the locations of the vehicles **10**. The GPS data may include an indication of a current location of the vehicle **10**. The GPS data and/or the telematics data may additionally or alternatively include travel history details regarding scene responses of each of the vehicles **10** and/or for vehicles leaving a certain location (e.g., the location **910** versus the location **920**). By way of example, the travel history details may include specific route information, time information, frequency of response information, and/or still other information. The vehicle controllers **800** of the vehicles **10** may be configured to acquire and provide vehicle data to the vehicle server **1020** over the network **1010**. The vehicle data may include information about the current state of charge ("SOC") of the ESS **700** of a respective vehicle **10** and/or the current state of health ("SOH") of components of the respective vehicle (e.g., the ESS **700**, the pump system **600**, etc.).

[0032] The user device **1050** may be any suitable device that facilitates user access to the vehicle server **1020**, the vehicle controller **800** of the vehicles **10**, the telematics system **1030**, and/or the GPS **1040** over the network **1010**. By way of example, the user device **1050** may be or include a personal electronic device, a computer (e.g., a laptop computer, a desktop computer, etc.), a tablet, a smart phone, and/or another electronic device. As described in greater herein, the user device **1050** may be configured to facilitate accessing a user portal through which (a) various tools and/or information may be accessed by a user and/or (b) user entered data can be input.

[0033] According to an exemplary embodiment, the vehicle server **1020** is configured to communicate with the vehicles **10** of the one or more vehicle fleets **900**, the charging stations **930**, the telematics system **1030**, the GPS **1040**, and/or the user device **1050** over the network **1010** to (**1**) receive or acquire (a) the vehicle data from the vehicles **10**, (b) the telematics data from the telematics system **1030**, (c) the GPS data from the GPS **1040**, and/or (d) the user entered data from the user device **1050** and/or (**2**) control the vehicles **10** and/or the charging stations **930** to dynamically modulate charging of the vehicles **10**. In some embodiments, a respective vehicle controller **800** is configured to acquire the telematics data for the vehicle **10** associated therewith from the telematics system **1030** and/or the GPS data for the vehicle **10** associated therewith from the GPS **1040**, and then the respective vehicle controller **800** is configured to transmit the vehicle data, the telematics data, and/or the GPS data associated with the vehicle **10** to the vehicle server **1020** (e.g., as a single vehicle profile for the vehicle **10**). As described in greater detail herein, the vehicle server **1020** (and/or the vehicle controller **800**) is configured to facilitate (a) evaluating the impact (e.g., cost, emissions, etc.) of ownership of an electric variant versus an equivalent internal combustion engine ("ICE") variant of the vehicle **10**, (b) evaluating charger sizes to identify a suitable charge for the vehicle **10** based on individual department needs, and (c) intelligently evaluating vehicle charging and performance requirements to facilitate dynamic charging management to minimize or optimize cost of ownership.

[0034] It should be understood that, while certain functionality may be described herein in the context of the vehicle server **1020**, such functionality may be performed or conducted by the combination of the vehicle server **1020** and the vehicle controllers **800**, or locally with just the vehicle controllers **800** (e.g., local communication between vehicles **10** at a respective location).

Impact of Ownership Tool

[0035] As shown in FIG. **4**, the vehicle server **1020** (and/or the vehicle controller **800**) is configured to facilitate accessing a first tool, shown as impact of ownership tool **1100**, with the user device **1050** and/or the user interface of the vehicle **10**. According to an exemplary embodiment, the impact of ownership tool **1100** facilitates evaluating the impact (e.g., cost, emissions, etc.) of ownership of an electric variant versus an ICE variant of the vehicle **10**. As shown in FIG. **4**, the impact of ownership tool **1100** provides a graphical user interface having a first portion or section, shown as vehicle model section **1102**, a second portion or section, shown as department response information section **1104**, a third section, shown as cost section **1106**, and a fourth section, shown as results section **1108**.

[0036] According to an exemplary embodiment, the vehicle model section **1102** facilitates entering or selecting (e.g., from a drop-down menu) a model of the vehicle **10** owned by a user or a model of the vehicle **10** for which a user desires to run analytical models for (e.g., prior to ordering the vehicle **10**). By way of example, the models may include the Pierce® Volterra™ municipal pumper fire apparatus, the Pierce® Volterra™ municipal aerial fire apparatus, the Oshkosh® Striker® Volterra™ ARFF vehicle, and/or other vehicle models. In some embodiments, the vehicle model section **1102** facilitates entering other inputs such manufacture year, vehicle generation, VIN number, etc. to more closely tailor the results of the impact of ownership tool **1100** to the specific vehicle of interest. In some embodiments, the impact of ownership tool **1100** is associated with a single vehicle model (i.e., a vehicle specific tool) and, therefore, does not include the vehicle model section **1102**. In such embodiments, multiple separate impact of ownership tools **1100** may be designed (e.g., built, coded, etc.) and accessed for each respective vehicle.

[0037] According to an exemplary embodiment, the department response information section **1104** facilitates entering, selecting (e.g., from drop-down menus), or acquiring various information associated with average response parameters or response requirements for a respective department. As shown in FIG. **4**, the department response information section **1104** includes a first input area, interface, or cell, shown as average number of trips box **1110**, that facilitates entering or selecting an average number of trips taken per day by a vehicle of the department; a second input area, interface, or cell, shown as average distance box **1112**, that facilitates entering or selecting an average round trip distance (e.g., in miles) per trip taken by the vehicle of the department; a third input area, interface, or cell, shown as average time away box **1114**, that facilitates entering or selecting an average time (e.g., in minutes) the vehicle is away from the station for each trip taken by the vehicle of the department; a fourth input area, interface, or cell, shown as average response time box **1116**, that facilitates entering or selecting an average time (e.g., in minutes) it takes the vehicle to respond to a scene; a fifth input area, interface, or cell, shown as expected lifespan box **1118**, that facilitates entering or selecting a lifespan (e.g., in years) that is expected of the vehicle by the department; and a sixth input area, interface, or cell, shown as location box **1120**, that facilitates entering or selecting a location (e.g., country, state, county, city, etc.) at which the department is located and the vehicle is or will be deployed. While described as being input by a user with the user device **1050**, in some embodiments, the impact of ownership tool **1100** automatically populates at least a portion of the information into the department response information section **1104** based on the telematics data, the GPS data, and/or the vehicle data for a respective vehicle **10** (e.g., if in service already) or other vehicles already being operated by the department.

[0038] According to an exemplary embodiment, the cost section **1106** facilitates entering, selecting (e.g., from drop-down menus), or acquiring various information associated with average costs or environmental impacts for operating fire apparatuses for a respective department. As shown in FIG. **4**, the cost section **1106** includes a seventh input area, interface, or cell, shown as CO_2e emission intensity box **1122**, associated with a CO_2e emission intensity (i.e., a ratio of CO_2e emissions from public electricity production and gross electricity production) at the deployment location of the vehicle; an eighth input area, interface, or cell, shown as electricity cost box **1124**, associated with a current (average) cost per kilowatt-hour of electricity at the deployment location of the vehicle; and a ninth input area, interface, or cell, shown as fuel cost box **1126**, associated with a current (average) cost per gallon of fuel (e.g., diesel) at the deployment location of the vehicle. In some embodiments, the impact of ownership tool **1100** automatically populates information or data into the CO_2e emission intensity box **1122**, the electricity cost box **1124**, and/or the fuel cost box **1126** based on the information entered into or selected at the location box **1120**. Such information or data automatically populated by the impact of ownership tool **1100** may be sourced from a database, an electricity provider's website, sustainability reports, and/or other sources. In some embodiments, the user can manually override the information automatically populated and enter user preferred values.

[0039] According to an exemplary embodiment, the results section **1108** facilitates displaying various results or outputs based on the data, information, etc. input and/or populated into the vehicle model section **1102**, the department response information section **1104**, and/or the cost section **1106**. As shown in FIG. **4**, the results section **1108** includes a first output area or cell, shown as energy cost savings box **1128**, a second output area or cell, shown as CO_2e savings box **1130**, a third output area or cell, shown as passenger car equivalent box **1132**, and a fourth output area or cell, shown as electric vs. ICE emissions box **1134**. The energy cost savings box **1128** provides a projected energy cost savings (e.g., in dollars) over the lifespan of the vehicle **10** by owning and operating the vehicle **10** rather than an equivalent ICE variant thereof. Such value may be estimated based on the projected electricity usage over the lifespan of the vehicle **10** versus the projected fuel usage (e.g., diesel) of the equivalent ICE variant thereof over the same lifespan. Energy cost inflation may be accounted for by utilizing historical data from the Energy Information Administration ("EIA") (e.g., from **1994** to present). Based on such historical data, this calculation may assume a first inflation rate (e.g., 2%) for electricity costs and a second inflation rate (e.g., 8%) for diesel fuel year-over-year. The CO_2e savings box **1130** provides a projected CO_2e emissions savings (e.g., in metric tons) over the lifespan of the vehicle **10** by owning and operating the vehicle **10** rather than an equivalent ICE variant thereof. To be conservative, such value may be estimated using a static value for emissions generated by electricity producers per kWh because electricity producers are continuing to increase energy production using renewable, non-CO_2 emitting sources (e.g., solar, wind, hydro, etc.). The passenger car equivalent box **1132** provides a projected emissions savings provided by the vehicle **10** in units of passenger cars' yearly emissions. Such comparison assumes the average yearly emissions for ICE passenger vehicles. The electric vs. ICE emissions box **1134** provides a projected amount or percentage of emission generated by the vehicle **10** over the lifespan of the vehicle **10** relative to an equivalent ICE variant thereof.

[0040] As shown in FIG. **5**, the impact of ownership tool **1100** is configured to generate and provide a first graph output, shown as energy costs over time graph **1140**, based on the inputs and outputs of the vehicle model section **1102**, the department response information section **1104**, the cost section **1106**, and/or the results section **1108**. The energy costs over time graph **1140** provides a first visual or graphical element, shown as electricity cost curve **1142**, a second visual or graphical element, shown as fuel cost curve **1144**, and a third visual or graphical element, shown as costs savings curve **1146**. The electricity cost curve **1142** provides a visual projection of the total electricity cost to operate the vehicle **10** over the lifespan of the vehicle **10**. The fuel cost curve **1144** provides a visual projection of the total fuel cost to operate an equivalent ICE variant of the vehicle **10** over the lifespan thereof. The costs savings curve **1146** provides a visual projection of the total energy cost savings from owning and operating the vehicle **10** relative to an equivalent ICE variant of the vehicle **10** over the lifespans thereof.

[0041] As shown in FIG. **6**, the impact of ownership tool **1100** is configured to generate and provide a second graph output, shown as lifetime energy costs and CO_2e emissions graph **1150**, based on the inputs and outputs of the vehicle model section **1102**, the department response information section **1104**, the cost section **1106**, and/or the results section **1108**. The lifetime energy costs and CO_2e emissions graph **1150** includes a first portion, shown as lifetime energy costs portion **1160**, and a second portion, shown as lifetime CO_2e emissions portion **1170**. The lifetime energy costs portion **1160** provides a first visual or graphical element, shown as lifetime electricity costs bar **1162**, and a second visual or graphical element, shown as lifetime fuel costs bar **1164**, that collectively facilitate comparing the projected lifetime electricity costs to operate the vehicle **10** and the projected lifetime fuel costs to operate an equivalent ICE variant of the vehicle **10**. The lifetime CO_2e emissions portion **1170** provides a third visual or graphical element, shown as lifetime electricity CO_2e emissions bar **1172**, and a fourth visual or graphical element, shown as lifetime fuel CO_2e emissions bar **1174**, that collectively facilitate comparing the projected lifetime CO_2e emissions to operate the vehicle **10** and the projected lifetime CO_2e emissions to operate an equivalent ICE variant of the vehicle **10**.

Charger Sizing Tool

[0042] As shown in FIG. **7**, the vehicle server **1020** (and/or the vehicle controller **800**) is configured to facilitate accessing a second tool, shown as charger sizing tool **1200**, with the user device **1050** and/or the user interface of the vehicle **10**. According to an exemplary embodiment, the charger sizing tool **1200** facilitates evaluating charger sizes to identify a suitable charging station **930** for the vehicle **10** based on individual department needs (e.g., based on past history, based on desired performance, etc.). As shown in FIG. **7**, the charger sizing tool **1200** includes a first input area, interface, or cell, shown as average energy usage box **1202**, associated with an average energy usage (e.g., in kWhr) during an average call, response, or trip and a second input area, interface, or cell, shown as average post-call SOC box **1204**, associated with an average SOC percentage of the ESS **700** following an average call, response, or trip. According to an exemplary embodiment, the charger sizing tool **1200** automatically populates information or data into the average energy usage box **1202** and the average post-call SOC box **1204** based on the information entered into or selected using the vehicle model section **1102**, the department response information section **1104**, and/or the cost section **1106** of the impact of ownership tool **1100**.

[0043] As shown in FIG. **7**, the charger sizing tool **1200** includes a third input area, interface, or cell, shown as charger size box **1206**, that facilitates entering or selecting (e.g., from a drop-down menu) a size (e.g., in kW) of a charger for the vehicle **10** and a fourth input area, interface, or cell, shown as size slider **1208**, that facilitates adjusting the value within the charger size box **1206** by selecting the left and right arrows thereof, or by manipulating the slider element thereof left and right. The charger sizing tool **1200** is configured to populate a first output area or cell, shown as recovery time box **1210**, based on the values of the average energy usage box **1202**, the average post-call SOC box **1204**, and the charger size box **1206**. The recovery time box **1210** provides a value indicating an amount of time it would take to recover the energy depleted from the ESS **700** during an average call with the vehicle **10** based on the current selected charger size. Accordingly, a user can evaluate which charger size is suitable to meet their specific needs based on average call response parameters and average dwell time at the station (i.e., time between response calls during which time the vehicle **10** can be recharged).

[0044] As shown in FIG. **7**, the charger sizing tool **1200** includes a fifth input area, interface, or cell, shown as SOC box **1212**, that facilitates entering or selecting (e.g., from a drop-down menu) a SOC value for the vehicle **10** of the user's choosing and a sixth input area, interface, or cell, shown as SOC slider **1214**, that facilitates adjusting the value within the SOC box **1212** by selecting the left and right arrows thereof, or by manipulating the slider element thereof left and right. The charger sizing tool **1200** is configured to populate a second output area or cell, shown as recharge time box **1216**, based on the values of the charger size box **1206** and the SOC box **1212**. The recharge time box **1216** provides a value indicating an amount of time it would take to recharge the vehicle **10** based on the current selected charger size and the user selected SOC value. Accordingly, a user can evaluate which charger size is suitable to meet their specific needs (e.g., whether a higher output charger or a lower output charger is needed to meet needs).

Cost of Ownership Optimization

[0045] According to an exemplary embodiment, the vehicle server **1020** (and/or the vehicle controller **800**) is configured to provide charge management cost projections and functionality for the vehicle **10** to inform the user of potential cost saving opportunities if the charge management functionality were implemented and facilitate reducing operating costs for the vehicle **10** when the charge management functionality is implemented. Specifically, the vehicle server **1020** (and/or the vehicle controller **800**) is configured to receive or acquire various inputs based on the vehicle data from the vehicle **10**, the telematics data from the telematics system **1030** (e.g., regarding operation of the vehicle **10**, other vehicles similar to the vehicle **10**, etc.), the GPS data from the GPS **1040** (e.g., regarding operation of the vehicle **10**, regarding operation of other vehicles within the same fleet or department, etc.), the user entered data from the user device **1050** and/or the user interface of the vehicle **10**, and/or still other data from other sources (e.g., the EIA, the environmental protection agency ("EPA"), original equipment manufacturers ("OEMs"), etc.). Examples of such inputs are outlined in Table 1 and Table 2 below.

[0046] Table 1 outlines various vehicle specific inputs for the vehicle **10** acquired from one or more sources. The one or more sources may include the OEM for the vehicle **10**, the EIA, the EPA, the telematics system **1030**, and/or the GPS **1040**. The vehicle specific inputs may include electric system efficiency, diesel system efficiency, annual electricity inflation rate, annual diesel inflation rate, energy per gallon of diesel, CO_2 emissions per gallon of diesel, CH_4 emissions per gallon of diesel, N_2O emissions per gallon of diesel, CO_2 equivalent emissions per CH_4 emissions, CO_2 equivalent emissions per N_2O emissions, average amount of fuel used per trip, average amount of electrical energy used per mile, average amount of idle energy consumption per trip, NOx emission per gallon of diesel, SO_2 emissions per gallon of diesel, battery capacity of the ESS **700**, charging energy efficiency of the ESS **700**, average amount of fuel used per moving time, average amount of idle energy consumption per trip, upper SOC limit for the batteries of the ESS **700**, lower SOC limit for the batteries of the ESS **700**, CO_2 equivalent emission per MWh of electric generation, NOx emissions per MWh of electric generation, SO_2 emissions per MWh of electric generation, and CO_2 emissions per gallon of diesel. It should be understood that the listed vehicle specific inputs are provided as examples, and additional, different, or fewer vehicle specific inputs may be used.

[0047] Table 2 outlines various department specific inputs for the vehicle **10** acquired from one or more sources. The one or more sources may include the departments power bill, the departments power agreement with their utilities provider, the EIA, the EPA, and the user and/or the telematics system **1030** (e.g., regarding operation of the vehicle **10**, regarding operation of other vehicles within the same fleet or department, etc.). The department specific inputs may include maximum station power demand, monthly energy usage, whether weekends are charged at off-peak rates, off-peak energy rate, off-peak power rate using maximum draw, peak 1 energy rate, peak 1 power rate using maximum draw, start time of peak 1 rates, peak 2 energy rate, peak 2 power rate using maximum draw, start time of peak 2 rates, peak 3 energy rate, peak 3 power rate using maximum draw, start time of peak 3 rates, stop time of peak 3 rates, other fees and baseline charges, average distance for trips, longest distance for trips, average number of trips per day, a maximum number of trips in a day, number of the vehicles **10** at a respective station, excepted lifespan for the vehicle **10**, deployment location for the vehicle **10**, cost of diesel per gallon, CO_2 equivalent emissions per MWh of electric generation, off-peak AM charge rate, peak 1 charge rate, peak 2 charge rate, peak 3 charge rate, and off-peak PM charge rate. It should be understood that the listed department specific inputs are provided as examples, and additional, different, or fewer department specific inputs may be used.

[0048] Based on the vehicle specific inputs and the department specific inputs, the vehicle server **1020** (and/or the vehicle controller **800**) is configured to perform one or more methods or processes (e.g., using models, using probability distributions, using optimization tools, etc.) to generate various outputs regarding the charge management cost projections and the charge management functionality. More specifically, the charge management projections can inform users of proper charger sizing, energy costs, emissions, and optimization parameters, which are provided below in Tables 3 and 4, and shown in FIG. **8**. The charge management functionality is described in greater detail below.

[0049] Table 3 outlines various per year outputs for the vehicle **10** generated by the vehicle server **1020** (and/or the vehicle controller **800**) based on the vehicle specific inputs and the department specific inputs. The per year outputs may include a managed charging energy cost per year (i.e., a cost to charge the vehicle **10** if the charge management functionality in enabled), a fixed or unmanaged charging energy cost per year (i.e., a cost to charge the vehicle **10** if the charge management functionality is disabled), a fuel cost per year to operate an equivalent ICE variant of the vehicle **10**, CO_2e savings per year relative to an equivalent ICE variant of the vehicle **10**, a recommended charger size for the charging station **930**, and a percentage of trips capable of being fulfilled over the year with the recommended charger size. It should be understood that the listed per year outputs are provided as examples, and additional, different, or fewer per year outputs may be generated.

[0050] Table 4 outlines various lifespan outputs for the vehicle **10** generated by the vehicle server **1020** (and/or the vehicle controller **800**) based on the vehicle specific inputs and the department specific inputs. The lifespan outputs may include a total amount of electricity used by the vehicle **10**, a total number of gallons of fuel used by the vehicle **10** (e.g., for pumping operations, for driving operations, etc.), a total number of gallons of fuel used by an equivalent ICE variant of the vehicle **10**, a total amount of CO_2e emissions for the vehicle **10**, a total amount of CO_2e emissions for an equivalent ICE variant of the vehicle **10**, a total amount of NOx emissions for the vehicle **10**, a total amount of NOx emissions for an equivalent ICE variant of the vehicle **10**, a total amount of SO_2 emissions for the vehicle **10**, a total amount of SO_2 emissions for an equivalent ICE variant of the vehicle **10**, a total cost of operation for the vehicle **10**, a total cost of operation for an equivalent ICE variant of the vehicle **10**, a total amount of cost savings from operating the vehicle **10** relative to an equivalent ICE variant of the vehicle **10**, a total amount of CO_2e savings from operating the vehicle **10** relative to an equivalent ICE variant of the vehicle **10**, a total amount of SO_2 savings from operating the vehicle **10** relative to an equivalent ICE variant of the vehicle **10**, and a total amount of NOx savings from operating the vehicle **10** relative to an equivalent ICE variant of the vehicle **10**. It should be understood that the listed lifespan outputs are provided as examples, and additional, different, or fewer lifespan outputs may be generated.

TABLE 1

Vehicle Specific Inputs			
Value	Units	Description	Source
80	percent	Electric system efficiency	OEM
27	percent	Diesel system efficiency	OEM
2.0	percent	Annual electricity inflation rate (1994-2022)	EIA
8.3	percent	Annual diesel inflation rate (1994-2022)	EIA
37.95	kWh/gallon	Energy per gallon of diesel	EPA
10.21	kg CO2/gallon	CO2 emissions per gallon of diesel	EPA
0.41	g CH4/gallon	CH4 emissions per gallon of diesel	EPA
0.60	g N2O/gallon	N2O emissions per gallon of diesel	EPA
25	g CO2e/g CH4	CO2 equivalent emissions per CH4 emissions	EPA
298	g CO2e/g N2O	CO2 equivalent emissions per N2O emissions	EPA
0.02	gal/trip	Average fuel used per trip	Telematics
2.40	kWh/mile	Average energy used per mile	Telematics
1.12	kWh/trip	Average idle energy consumption per trip	Telematics
0.03	kg NOx/gallon	NOx emissions per gallon of diesel	EPA DEQ
0.05	g SO2/gallon	SO2 emissions per gallon of diesel	EPA Limit
155	kWh	Vehicle battery capacity	OEM
97	percent	Charging energy efficiency	OEM
0.02	gal/min	Average fuel used per moving time	Telematics
0.33	kWh/trip	Average energy used per moving time	Telematics
1.12	kWh/trip	Average idle energy consumption per trip	Telematics
96	percent	Battery upper SOC limit	Telematics
20	percent	Battery lower SOC limit	Telematics

TABLE 1-continued

Vehicle Specific Inputs			
Value	Units	Description	Source
390.2	kg CO2e/MWh	CO2 equiv. emissions per MWh of electric generation	EPA
0.2	kg NOx/MWh	NOx emissions per MWh of electric generation	EPA
0.3	kg SO2/MWh	SO2 emissions per MWh of electric generation	EPA
10.4	kg CO2e/gallon	CO2e emissions per gallon of diesel	EPA

TABLE 2

Department Specific Inputs			
Value	Units	Description	Source
40	kW	Maximum station power demand	Power bill
10000	kWh	Monthly energy usage	Power bill
False	true/false	Weekend is off-peak	Power agreement
0.09	$/kWh	Off-peak energy rate	Power agreement
0.08	$/kWh/day	Off-peak power rate w/maximum power draw	Power agreement
0.11	$/kWh	Peak 1 energy rate	Power agreement
0.10	$/kWh/day	Peak 1 power rate using maximum draw	Power agreement
0.11	$/kWh	Peak 2 energy rate	Power agreement
0.10	$/kWh/day	Peak 2 power rate using maximum draw	Power agreement
0.11	$/kWh	Peak 3 energy rate	Power agreement
0.20	$/kWh/day	Peak 4 power rate using maximum draw	Power agreement
180.00	$/month	Other fees & baseline charge	Power agreement
10:00	time	Start of peak 1 rates	Power agreement
13:00	time	Start of peak 2 rates	Power agreement
18:00	time	Start of peak 3 rates	Power agreement
21:00	time	Stop of peak 3 rates	Power agreement
8.0	miles	Normal trips are 0 to	Department
30.0	miles	The longest emergency trip is	Department
9.0	calls	Normal days have 0 to	Department
30.0	calls	A rare busy day has	Department
1.0	trucks	Number of station electric trucks	Department
12	years	Expected lifespan of vehicle	Department
U.S.	region	Vehicle deployment location	Department
4.69	$/gallon	Cost of diesel per gallon	EIA/Department
390.2	kg CO2e/MWh	CO2e emissions per MWh of elec. generation	EPA
20.5	kW	Off-peak AM charge rate	Dept. or Optimized
0.0	kW	Peak 1 charge rate	Dept. or Optimized
0.0	kW	Peak 2 charge rate	Dept. or Optimized
0.0	kW	Peak 3 charge rate	Dept. or Optimized
20.2	kW	Off-peak PM charge rate	Dept. or Optimized
45.0	kW	unmanaged	Calculated

TABLE 3

Per Year Outputs			
Value	Units	Description	Source
4200	$	Managed charging energy cost per year	Calculated
11900	$	Fixed charge rate energy cost per year	Calculated
12500	$	Traditional diesel fire apparatus cost per year	Calculated
13200	kg	CO2e savings vs diesel fire apparatus per year	Calculated
55	kW	Recommended charger size	Calculated
99.7	percent	Trips fulfilled with recommended charger size	Calculated

TABLE 4

Lifespan Outputs			
Value	Units	Description	Source
408135	kWh/lifespan	kWh of electricity used by e-fire apparatus over lifespan	Calculated
1560	gal/lifespan	Gallons of diesel used for pumping over lifespan	Calculated
33426	gal/lifespan	Gallons of diesel used for diesel equivalent over lifespan	Calculated
172396	kg CO2e	Over e-fire apparatus' lifespan	Calculated

TABLE 4-continued

Lifespan Outputs			
Value	Units	Description	Source
147	kg NOx	Over e-fire apparatus' lifespan	Calculated
196	kg SO2	Over e-fire apparatus' lifespan	Calculated
331369	kg CO2e	Over diesel fire apparatus' lifespan	Calculated
10891	kg NOx	Over diesel fire apparatus' lifespan	Calculated
2	kg SO2	Over diesel fire apparatus' lifespan	Calculated
50400	$/lifespan	Over e-fire apparatus' lifespan	Calculated
150000	$/lifespan	Over diesel fire apparatus' lifespan	Calculated
99600	$ saved	Electric vs diesel fuel savings over lifespan	Calculated
158973	kg CO2e saved	Electric vs diesel CO2e emissions over lifespan	Calculated
−195	kg SO2 saved	Electric vs diesel SO2 emissions over lifespan	Calculated
10744	kg NOx saved	Electric vs diesel NOx emissions over lifespan	Calculated

[0051] As shown in FIG. **8**, the vehicle server **1020** (and/or the vehicle controller **800**) is configured to provide or facilitate accessing a third tool, shown as charge management tool **1300**. The charge management tool **1300** is configured to provide a graphical user interface displaying various statistics for comparing parameters when the charge management functionality in disabled versus when the charge management functionality is enabled. The parameters include monthly charging costs, total/lifetime charging costs, monthly percent of on-peak versus off-peak charging, monthly cost per kWh, and total/lifetime cost per kWh. The charge management functionality is described in greater detail herein.

Dynamic Charge Management

[0052] According to an exemplary embodiment, the vehicle server **1020** (and/or the vehicle controller **800**) is configured to provide the charge management functionality to make dynamic charging decisions regarding each of the vehicles **10** within a respective vehicle fleet **900** that are connected to the charging stations **930**. Such dynamic charging decisions may be implemented based on the above cost of ownership optimization and if the user has such functionality enabled.

[0053] According to an exemplary embodiment, the vehicle server **1020** (and/or the vehicle controller **800**) is configured to receive an indication of vehicles **10** within a respective vehicle fleet **900** connected to the charging stations **930** (e.g., from the charging stations **930**) and determine a charge readiness score for each of the vehicles **10** that are charging or attempting to be charged via a respective charging station **930** based on the vehicle data, the telematics data, the GPS data, and/or the user entered data. The charge readiness score may be based on one or more factors including (a) a vehicle response history profile of a respective vehicle **10**, (b) a station response history profile of a station or location at which the respective vehicle **10** is charging or attempting to be charged with a respective charging station **930**, (c) a current cost of electricity at the location at which the respective vehicle **10** is charging or attempting to be charged, (d) an expected future cost of electricity at the location at which the respective vehicle **10** is charging or attempting to be charged, include a current SOC of the respective vehicle **10**, and/or (f) a current SOC of other vehicles **10** charging or attempting to be charged at the same location of the respective vehicle **10**, among other suitable factors.

[0054] The vehicle response history profile may indicate how often a respective vehicle **10** is dispatched to a response scene, at what times the respective vehicle **10** is typically dispatched to a response scene, how far the respective vehicle **10** typically has to travel to get to a response scene, battery depletion patterns for the respective vehicle **10**, and/or any other trends regarding the respective vehicle **10**. The station response history profile may indicate how often the vehicles **10** stationed at a respective station are dispatched to a response scene, at what times the vehicles **10** stationed at the respective station are typically dispatched to a response scene, how far the vehicles **10** stationed at the respective station typically have to travel to get to a response scene, battery depletion patterns for the vehicles **10** stationed at the respective station, and/or any other trends regarding the vehicles **10** stationed at the respective station. The expected future cost of electricity may be based on (a) the current time, date, and/or weather/temperature conditions and (b) past cost history during similar times (e.g., season, month, day, time of the day, etc.), during similar weather and temperature conditions (e.g., snow, rain, sunny, severe cold, extreme heat, etc.), etc.

[0055] Generally, after determining the charge readiness score for each of the vehicles **10** within a respective vehicle fleet **900** and/or at a respective location (e.g., the location **910**, the location **920**, etc.), the vehicle server **1020** (and/or the vehicle controller **800**) may be configured to dynamically charge the vehicles **10** within the respective vehicle fleet **900** and/or at the respective location. For example, the vehicle server **1020** (and/or the vehicle controller **800**) may prevent charging of a first vehicle **10** in favor of a second vehicle **10**. As another example, the vehicle server **1020** (and/or the vehicle controller **800**) may prevent charging of a respective vehicle **10** based on expected demand of that vehicle and current electricity costs. As yet another example, the vehicle server **1020** may prevent charging a respective vehicle **10** if the charge readiness score is below a charge readiness threshold. These and other examples are further described herein.

[0056] A charge readiness score for a respective vehicle **10** may be lowered or reduced based on (a) the current cost of electricity being higher than the expected cost of electricity later that day or night, (b) it currently being unlikely that the respective vehicle **10** will need to be dispatched to a response scene (e.g., based on the vehicle response history profile, the station response history profile, etc.), (c) another vehicle **10** at the same station having a relatively high or higher SOC (e.g., such that the other vehicle **10** is sufficient to respond to an upcoming dispatch call), and/or (d) the respective vehicle **10** having a relatively high SOC (e.g., such that the respective vehicle **10** can respond to an upcoming dispatch call without requiring charging), among other possible factors. Whereas, a charge readiness score for a respective vehicle **10** may be increased or higher based on (a) the current cost of electricity being lower than the expected cost of electricity later that day or night, (b) it currently being likely that the respective vehicle **10** will need to be dispatched to a response scene (e.g., based on the vehicle response history profile, the station response history profile, etc.), (c) another vehicle **10** at the same station having a relatively low or lower SOC (e.g., such that the other vehicle **10** is sufficient to respond to an upcoming dispatch call) or no other vehicle **10** being stationed at the location of the respective vehicle **10**, and/or (d) the respective vehicle **10** having a relatively low SOC (e.g., such that the respective vehicle **10** may not be able to properly respond to an upcoming dispatch call without being charged), among other possible factors.

[0057] Further, the charge readiness score for a respective vehicle **10** may be different depending on the station at which the respective vehicle **10** is currently stationed, all other things considered equal. For example, under the same conditions (e.g., cost of electricity, current SOC, etc.), one station may historically be more active than another station such that moving the respective vehicle **10** from one station to another may significantly impact how charging of that vehicle **10** is handled by the vehicle server **1020** (and/or the vehicle controller **800**).

[0058] After determining the charge readiness score for a respective vehicle **10** that is plugged into or attempting to be plugged into a respective charging station **930**, the vehicle server **1020** (and/or the vehicle controller **800**) may be configured to send a signal to the respective vehicle **10** (or the respective charging station **930**) to either prevent charging from starting, stop charging if already charging, start charging if not already charging, or continue charging if already charging. As an example, if a first vehicle **10** is already charging and a second vehicle **10** is subsequently plugged in, the vehicle server **1020** (and/or the vehicle controller **800**) (and/or the vehicle controller **800**) may determine whether the first vehicle **10** should continue charging or stop charging based on the second vehicle **10** being plugged in. As another example, the current price of electricity may shift during charging such that the vehicle server **1020** (and/or the vehicle controller **800**) may determine whether the first vehicle **10** should continue charging or stop charging based on the shift in price. As yet another example, a first vehicle **10** that is currently charging may be dispatched to a scene, and as such, the charge readiness score for a second vehicle **10** may shift higher due to the likelihood of having to now be dispatched. In such a scenario, the vehicle server **1020** (and/or the vehicle controller **800**) may determine whether to start charging the second vehicle **10** or continue not charging the second vehicle **10**.

[0059] In some embodiments, the vehicle server **1020**, the vehicle controller **800** of a respective vehicle **10**, and/or a respective charging station **930** provide an indication of whether charging is occurring or currently suspended or prevented. In some embodiments, an operator (e.g., at the location at which the charging is being attempted for the respective vehicle **10**) may be able to override the suspension in charging (e.g., via a user interface of the respective vehicle **10**, via a user interface of the respective charging station **930**, via a user device (a smart phone, a computer, etc.) in communication with the vehicle server **1020**, etc.). In some embodiments, if connection to the vehicle server **1020** is lost, the respective charging station **930** and/or the vehicle controller **800** of the respective vehicle **10** may be configured to default to permitting charging. In some embodiments, if connection to the vehicle server **1020** is lost, the vehicle controller **800** of the respective vehicle **10** makes the charging decision based on the information available to it. In some embodiments, the vehicle server **1020** (and/or the vehicle controller **800**) is configured to permit a respective vehicle **10** to be charged to a certain SOC threshold (e.g., a predefined threshold, a dynamic threshold based on the vehicle response history profile and the station response history profile, etc.) and then suspend charging once the certain SOC threshold is reached and then permit charging later on when electricity prices have dropped.

[0060] Accordingly, the vehicle evaluation, charging, and optimization system **1000** is configured to maintain a respective vehicle **10**, a respective fire station (e.g., having multiple vehicles **10**), and/or an entire respective vehicle fleet **900** ready for dispatch calls, but doing so in a manner that reduces the operating costs to keep the vehicles **10** charged and ready to be dispatched.

Other Functionality

[0061] According to an exemplary embodiment, the various charging related functionality described herein can be applied to other subsystems of the vehicle **10** such as the pump system **600** and/or the aerial ladder **50**. By way of example, the vehicle server **1020** and/or the vehicle controller **800** may provide a pump tool configured to store pump curves for the pump system **600** and receive or acquire pump inputs including type of pump, net inlet pump pressure value (e.g., positive pressure value from hydrant, negative pressure value from a ground based tank, a net zero pressure from an onboard tank, etc.), and a desired or required output flow value. Based on the pump curves and the pump inputs, the pump tool may be configured to calculate electric energy consumption and a burn down rate of stored, onboard energy to provide the desired output flow. Such a pump tool may be used with the user device **1050** when configuring the vehicle **10** pre-manufacture so that the selected pump can meet specific needs of a respective department. Such a pump tool may additionally or alternatively be used in real-time during pumping at a scene to provide real-time energy usage and depletion on the user interface of the vehicle **10** (e.g., an in-cab interface, a pump house display, etc.).

[0062] By way of another example, the vehicle server **1020** and/or the vehicle controller **800** may provide an aerial ladder tool configured to store a load curve for the aerial ladder **50** and monitor ladder operation data (e.g., position, extension, retraction, rotation, lift, etc.) regarding operation of the aerial ladder **50**. Based on the load curve and the ladder operation data, the aerial ladder tool may be configured to calculate electric energy consumption and a burn down rate of stored, onboard energy to continue operating the actuators of the aerial ladder **50** (e.g., hydraulic pump driven by an electric motor, driven by an ePTO, etc.) to provide the current operation of the aerial ladder. Such an aerial ladder tool may be used in real-time during aerial operation at a scene to provide real-time energy usage and depletion on the user interface of the vehicle **10** (e.g., an in-cab interface, an interface on the aerial ladder, etc.).

[0063] 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.

[0064] 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).

[0065] 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.

[0066] 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.

[0067] 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.

[0068] 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.

[0069] 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.

[0070] It is important to note that the construction and arrangement of the 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.

1. An electrified fire apparatus system comprising:

one or more processing circuits including one or more memory devices coupled to one or more processors, the one or more memory devices configured to store instructions thereon that, when executed by the one or more processors, cause the one or more processors to:

acquire first information regarding (a) at least one of average response parameters or response requirements for a respective fire department and (b) a location of the respective fire department;

acquire second information regarding at least one of average costs or environmental impacts for operating one or more fire apparatuses associated with the respective department; and

provide a results graphical user interface for display providing one or more results for a respective electrified fire apparatus based on the first information and the second information, the one or more results including at least one of:

(a) an energy cost savings output providing a projected energy cost savings over a lifespan of the respective electrified fire apparatus by owning and operating the respective electrified fire apparatus rather than an equivalent internal combustion engine (ICE) variant thereof;

(b) a CO_2e savings output providing a projected CO_2 emissions savings over the lifespan of the respective electrified fire apparatus by owning and operating the respective electrified fire apparatus rather than the equivalent ICE variant; or

(c) an emissions output providing a projected amount or percentage of emission generated by the respective electrified fire apparatus over the lifespan of the respective electrified fire apparatus relative to the equivalent ICE variant.

2. The electrified fire apparatus system of claim 1, wherein the instructions cause the one or more processors to acquire a user input regarding the respective electrified fire apparatus that the respective fire department owns or is considering purchasing, and wherein the one or more results are additionally based on the user input.

3. The electrified fire apparatus system of claim 1, wherein the instructions cause the one or more processors to acquire at least one of telematics data, GPS data, or vehicle data associated with the respective fire department, and wherein at least a portion of the first information is automatically acquired without user input based on the at least one of the telematics data, the GPS data, or the vehicle data.

4. The electrified fire apparatus system of claim 1, wherein at least a portion of the second information is automatically acquired without user input based on the location.

5. The electrified fire apparatus system of claim 1, wherein the second information includes a current electricity cost per kilowatt-hour at the location and a current fuel cost per gallon at the location, wherein the one or more results include the energy cost savings output, and wherein the projected energy cost savings is estimated based on a projected electricity usage over the lifespan of the respective electrified fire apparatus versus a projected fuel usage of the equivalent ICE variant over the lifespan based on (a) the at least one of the average response parameters or response requirements, (b) the current electricity cost per kilowatt-hour at the location, and (c) the current fuel cost per gallon at the location.

6. The electrified fire apparatus system of claim 5, wherein the projected energy cost savings is estimated based on (d) a first inflation rate for the current electricity cost per kilowatt-hour and (e) a second, different inflation rate for the current fuel cost per gallon.

7. The electrified fire apparatus system of claim 5, wherein the energy cost savings output includes a graph including a first cost curve associated with the respective electrified fire apparatus over the lifespan, a second cost curve associated with the equivalent ICE variant over the lifespan, and a cost savings curve associated with cost savings from owning and operating the respective electrified fire apparatus relative to the equivalent ICE variant over the lifespan.

8. The electrified fire apparatus system of claim 1, wherein the one or more results include the CO_2e savings output.

9. The electrified fire apparatus system of claim 8, wherein the one or more results include the energy cost savings output and the CO_2e savings output, and wherein the energy cost savings output and the CO_2e savings output are provided via a bar graph.

10. The electrified fire apparatus system of claim 1, wherein the one or more results include the emissions output.

11. The electrified fire apparatus system of claim 1, wherein the one or more results include the energy cost savings output, the CO_2e savings output, and the emissions output.

12. The electrified fire apparatus system of claim 1, wherein the instructions provide a charger sizing tool graphical user interface for display that facilitates evaluating charger sizes to identify a suitable charging station for the respective electrified fire apparatus based on individual needs of the respective fire department.

13. The electrified fire apparatus system of claim 12, wherein the charger sizing tool graphical user interface includes a first input area associated with an average energy usage during or an average state of charge following an average call for the respective fire department and a second input area that facilitates entering or selecting a size of a charger, wherein the instructions cause the one or more processors to:

acquire third information via the first input area;

acquire fourth information via the second input area; and

provide a recovery time output based on the third information and the fourth information, the recovery time output including a value indicating an amount of time it would take to recover energy depleted from the respective electrified fire apparatus following the average call for the respective fire department based on the size of the charger.

14. The electrified fire apparatus system of claim 13, wherein the instructions cause the one or more processors to automatically populate the third information into the first input area based on at least one of the first information or the second information.

15. An electrified fire apparatus system comprising:

a non-transitory computer-readable medium having instructions stored thereon that, when executed by one or more processors, cause the one or more processors to:

acquire first information regarding (a) at least one of average response parameters or response requirements for a respective fire department and (b) a location of the respective fire department;

acquire second information regarding at least one of average costs or environmental impacts for operating one or more fire apparatuses associated with the respective department; and

provide a results graphical user interface for display providing one or more results for a respective electrified fire apparatus based on the first information and the second information, the one or more results including at least one of:

(a) an energy cost savings output providing a projected energy cost savings over a lifespan of the respective electrified fire apparatus by owning and operating the respective electrified fire apparatus rather than an equivalent internal combustion engine (ICE) variant thereof;

(b) a CO_2e savings output providing a projected CO_2e emissions savings over the lifespan of the respective electrified fire apparatus by owning and operating the respective electrified fire apparatus rather than the equivalent ICE variant; or

(c) an emissions output providing a projected amount or percentage of emission generated by the respective electrified fire apparatus over the lifespan of the respective electrified fire apparatus relative to the equivalent ICE variant.

16. The electrified fire apparatus system of claim **15**, wherein the instructions cause the one or more processors to acquire at least one of telematics data, GPS data, or vehicle data associated with the respective fire department, and wherein at least a portion of the first information is automatically acquired without user input based on the at least one of the telematics data, the GPS data, or the vehicle data.

17. The electrified fire apparatus system of claim **15**, wherein at least a portion of the second information is automatically acquired without user input based on the location.

18. The electrified fire apparatus system of claim **15**, wherein the one or more results include the energy cost savings output, the CO_2e savings output, and the emissions output.

19. The electrified fire apparatus system of claim **15**, wherein the instructions cause the one or more processors to acquire a user input regarding the respective electrified fire apparatus that the respective fire department owns or is considering purchasing, and wherein the one or more results are additionally based on the user input.

20. An electrified fire apparatus system comprising:

a non-transitory computer-readable medium having instructions stored thereon that, when executed by one or more processors, cause the one or more processors to:

acquire first information regarding at least one of average response parameters or response requirements for a respective fire department;

acquire second information regarding a respective electrified fire apparatus that the respective fire department owns or is considering purchasing; and

provide at least one of (a) a recommendation for a size of a charger based on the first information and the second information or (b) a recovery time output based on the first information, the second information, and the size of the charger, the recovery time output including a value indicating an amount of time it would take to recover energy depleted from the respective electrified fire apparatus following an average call for the respective fire department based on the size of the charger.

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