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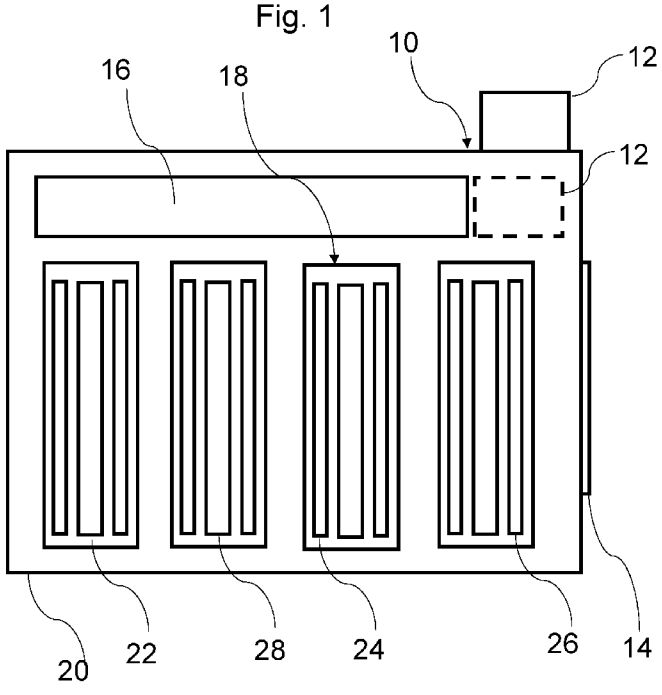
(54) Title: BATTERY PACKAGING

Fig. 1



(57) Abstract: Disclosed is a computer-implemented method for providing material identifier package usable for recycling of batteries, the method comprising the steps of: - providing at least one battery identifier and corresponding material configuration data associated with at least one component of the battery to be recycled; - determining at least one material identifier package by relating the at least one material configuration provided by the material configuration data to at least one material configuration processable by at least one plant; - providing the at least one material identifier package usable for recycling batteries including the at least one battery identifier.

[Continued on next page]

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BATTERY PACKAGING

TECHNICAL FIELD

The present disclosure relates to computer-implemented methods for providing material identifier package usable for recycling of batteries and respective systems, apparatuses, uses, computer elements.

TECHNICAL BACKGROUND

The general background of this disclosure concerns the recycling of batteries. Battery recycling is a subject of growing interest in a world with an increasing amount of portable electronic devices and automation. It is to be expected that a growing number of spent lithium-ion batteries will emerge with the advent of e-mobility. Since batteries contain important transition metals such as, cobalt, nickel, lithium, spent lithium-ion batteries may form a valuable source of raw materials for production of lithium-ion batteries. For that reason, increased research work has been performed with the goal of recycling transition metals and lithium from used lithium-ion batteries, or from batteries or parts thereof that do not meet the specifications and requirements; such off-spec materials and production waste may as well be a source of recycled materials.

The battery recycling process is highly decentral and inflexible. In view of the increasing need for battery recycling, there is a need to operate the recycling process in a more reliable and flexible manner. US2016371658 discloses (i) identifying, using a mobile device, a recyclable material based on a detected oscillation frequency of an oscillator associated with the recyclable material; and (iii) creating, by the controller, scheduling instructions for the identified recyclable material. WO2013184217 discloses methods, systems, and apparatuses for receiving a first plurality of product identifiers associated with products purchased by a consumer to form a purchase record. A second plurality of product identifiers associated with products recycled by the consumer is received. A record of recycled purchased products by the consumer is authenticated. US2014106185 discloses that a rechargeable battery may be recycled through a cycle that includes one or more of determining a battery condition while the rechargeable battery may be used in a networkable device, updating a rechargeable battery database with the battery condition over a network, determining recycling instructions, and outputting the recycling instructions on the networkable device.

SUMMARY OF THE INVENTION

Disclosed is a computer-implemented method for providing material identifier package usable for recycling batteries, the method comprising the steps of:

- providing at least one battery identifier and corresponding material configuration data associated with at least one component of the battery to be recycled;
- determining at least one material identifier package by relating the at least one material configuration provided by the material configuration data to at least one material configuration processable or to be processed by at least one plant;
- providing the at least one material identifier package usable for recycling batteries including the at least one battery identifier.

Disclosed is a computer-implemented method for providing material identifier package in a decentral computing environment usable for recycling of materials contained in products or for operating a product recycling process for recycling of materials contained in products associated with at least one product identifier, the method comprising the steps of:

- providing at least one product identifier and corresponding material configuration data associated with at least one component of the product to be recycled, wherein the material configuration data associated with the material used to produce the product or the component of the product is provided by a decentral computing node associated with the producer producing or using the material, optionally wherein the material configuration data associated with the material used to produce the product or the at least one component of the product is accessed by a decentral computing node associated with one or more recycling system(s) or classification instructions;
- determining at least one material identifier package by relating the at least one material configuration provided by the material configuration data to at least one material configuration processable by at least one plant;
- providing the at least one material identifier package usable for recycling of materials contained in products including the at least one product identifier,
- preferably operating the recycling process by providing the material identifier package for controlling and/or monitoring recycling system(s).

Disclosed is a computer-implemented method for operating a battery recycling process by providing at least one material identifier package, the method comprising the steps of:

- providing at least one battery identifier and corresponding material configuration data associated with at least one component of the battery to be recycled;
- determining at least one material identifier package by relating the at least one material configuration provided by the material configuration data to at least one material configuration processable or to be processed by at least one plant data;
- providing the at least one material identifier package for operating the battery recycling process including the at least one battery identifier.

Disclosed is a computer-implemented method for operating a product recycling process for recycling of materials contained in products associated with at least one product identifier, the method comprising the steps of:

- providing at least one product identifier and corresponding material configuration data associated with at least one component of the product to be recycled;
- determining at least one material identifier package by relating the at least one material configuration provided by the material configuration data to at least one material configuration processable by at least one plant;
- providing the at least one material identifier package usable for recycling of materials contained in products including the at least one product identifier, wherein the at least one material identifier package includes a gathering of product identifiers associated with at least one product or at least one component of the product to be recycled and with the at least one material configuration processable by at least one recycling plant,
- operating based on the at least one material identifier package the product recycling process for recycling of materials contained in products associated with the at least one product identifier.

Disclosed is a computer-implemented method for operating a product recycling process by providing at least one material identifier package, the method comprising the steps of:

- providing at least one product identifier and corresponding material configuration data associated with at least one component of the product to be recycled;
- determining at least one material identifier package by relating the at least one material configuration provided by the material configuration data to at least one material configuration processable by at least one plant;
- operating a product recycling process by providing the at least one material identifier package usable for recycling of materials contained in products including the at least one product identifier.

Further disclosed is an apparatus for providing material identifier package usable for recycling batteries, the apparatus comprising: one or more computing nodes; and one or more computer-readable media having thereon computer-executable instructions that are structured such that, when executed by the one or more computing nodes, cause the apparatus to perform the following steps:

- providing at least one battery identifier and corresponding material configuration data associated with at least one component of the battery to be recycled;
- determining at least one material identifier package by relating the at least one material configuration provided by the material configuration data to at least one material configuration processable or to be processed by at least one plant;
- providing the at least one material identifier package usable for recycling batteries including the at least one battery identifier.

Further disclosed is an apparatus for operating a battery recycling process by providing at least one material identifier package, the apparatus comprising: one or more computing nodes; and one or more computer-readable media having thereon computer-executable instructions that are structured such that, when executed by the one or more computing nodes, cause the apparatus to perform the following steps:

- providing at least one battery identifier and corresponding material configuration data associated with at least one component of the battery to be recycled;
- determining at least one material identifier package by relating the at least one material configuration provided by the material configuration data to at least one material configuration processable or to be processed by at least one plant data;
- providing the at least one material identifier package for operating the battery recycling process including the at least one battery identifier.

Disclosed is an apparatus for providing material identifier package in a decentral computing environment usable for recycling of materials contained in products or for operating a product recycling process for recycling of materials contained in products associated with at least one product identifier, the apparatus comprising: one or more computing nodes; and one or more computer-readable media having thereon computer-executable instructions that are structured such that, when executed by the one or more computing nodes, cause the apparatus to perform the following steps:

- providing at least one product identifier and corresponding material configuration data associated with at least one component of the product to be recycled, wherein the material configuration data associated with the material used to produce the product or the at least one component of the product is accessed by a decentral computing node associated with one or more recycling system(s), wherein the material configuration data associated with the material used to produce the product or the component of the product is provided by a decentral computing node associated with the producer producing or using the material;
- determining at least one material identifier package by relating the at least one material configuration provided by the material configuration data to at least one material configuration processable by at least one plant;
- providing the at least one material identifier package usable for recycling of materials contained in products including the at least one product identifier,
- preferably operating the recycling process by providing the material identifier package for controlling and/or monitoring recycling system(s).

Disclosed is an apparatus for operating a product recycling process for recycling of materials contained in products associated with at least one product identifier, the apparatus comprising: one or more computing nodes; and one or more computer-readable media having thereon computer-executable instructions that are structured such that, when executed by the one or more computing nodes, cause the apparatus to perform the following steps:

- providing at least one product identifier and corresponding material configuration data associated with at least one component of the product to be recycled;
- determining at least one material identifier package by relating the at least one material configuration provided by the material configuration data to at least one material configuration processable by at least one plant;
- providing the at least one material identifier package usable for recycling of materials contained in products including the at least one product identifier, wherein the at least one material identifier package includes a gathering of product identifiers associated with at least one product or at least one component of the product to be recycled and with the at least one material configuration processable by at least one recycling plant,
- operating based on the at least one material identifier package the product recycling process for recycling of materials contained in products associated with the at least one product identifier.

Further disclosed is an apparatus for operating a product recycling process by providing at least one material identifier package, the apparatus comprising: one or more computing nodes; and one or more computer-readable media having thereon computer-executable instructions that are structured such that, when executed by the one or more computing nodes, cause the apparatus to perform the following steps:

- providing at least one product identifier and corresponding material configuration data associated with at least one component of the product to be recycled;
- determining at least one material identifier package by relating the at least one material configuration provided by the material configuration data to at least one material configuration processable by at least one plant;
- operating a product recycling process by providing the at least one material identifier package usable for recycling of materials contained in products including the at least one product identifier.

Further disclosed is the use of a battery comprising at least one battery identifier element in any of the methods disclosed herein or with any of the apparatuses disclosed herein. Further disclosed is a method for using a battery comprising at least one battery identifier element, the method comprising the steps of: providing the battery identifier by reading the battery identifier element and generating at least one material identifier package as provided according to any of the methods disclosed herein or by any of the apparatuses disclosed herein.

Further disclosed is the use of the material identifier package as provided according to any of the methods disclosed herein or by any of the apparatuses disclosed herein to sort, collect, transport, store and/or recycle at least one component of a battery to be recycled. Further disclosed is a method for sorting, collecting, transporting, storing and/or recycling at least one component of a battery to be recycled, the method comprising the steps of: providing material identifier package as provided according to any of the methods disclosed herein or by any of the apparatuses disclosed herein, generating sorting, collecting, transport, storing and/or recycling instructions based on the material identifier package and providing the sorting, collecting, transport, storing and/or recycling instructions.

Further disclosed is a method for sorting, collecting, transporting, storing and/or recycling at least one component of a battery to be recycled, the method comprising the steps: providing at least one material identifier package generated according to any of the methods disclosed herein; generating sorting, collecting, transporting, storing and/or recycling instructions based

on the provided material identifier package and providing sorting, collecting, transporting, storing and/or recycling instructions.

Further disclosed is an apparatus for sorting, collecting, transporting, storing and/or recycling at least one component of a battery to be recycled, the apparatus comprising: one or more computing nodes; and one or more computer-readable media having thereon computer-executable instructions that are structured such that, when executed by the one or more computing nodes, cause the apparatus to perform the following steps: providing at least one material identifier package generated according to any of the methods disclosed herein; generating sorting, collecting, transporting, storing and/or recycling instructions based on the provided material identifier package and providing sorting, collecting, transport, storing and/or recycling instructions.

Further disclosed is a computer element, such as a computer program or a computer readable storage medium, with instructions, which, when executed by one or more computing node(s) of a computing environment, are configured to carry out steps of any of the methods disclosed herein and/or to carry out steps as provided by any of the apparatuses disclosed herein.

EMBODIMENTS

Any disclosure and embodiments described herein relate to methods, systems, uses, apparatuses and computer elements disclosed herein and vice versa. Benefits provided by any of the embodiments and examples provided herein equally apply to all other embodiments and examples and vice versa.

Advantageously the disclosure referred to herein provides an efficient, sustainable and robust way for operating recycling processes. By virtually sorting and/or gathering at least one component of the battery to be recycled and by virtually packaging the at least one component of the battery to be recycled based on the material configuration, the resulting material configuration of the recycled material can be virtually tracked. Such tracking may be provided across the recycling process at different stages to different participants including producers. Through tracking the components via an identity-based data footprint in a decentral computing environment, operating the recycling process is simpler, since it is digitally operated rather than

physically. Such digital operation reduces the complexity of the physical processing environment. For instance, the recycling process and plant operations can be simplified. E.g. complex separation processes due to unsuitable mixtures in the recycling feed can be avoided and purification or other process steps become less demanding. In particular, by way of identifier-based sorting or collecting the waste material fed into the recycling process can be managed with respect to material configuration or chemical composition. Additionally, the quality of the recyclate can be increased since the composition of the recycled material may be tailored to production needs through the recycling chain. As a result, by virtually sorting according to the composition of the recycled materials through the recycling process stages, the quality of the recyclate and the material produced from such recyclate can be maintained compared to materials produced from mere natural sources.

Battery may denote any structure configured to store electric power based on an electrochemical basis. Batteries may be structures comprising a group of two or more cells connected together and are not limited thereto. The battery may include a lithium-ion battery. The battery may be a battery as used in automobiles with multiple cells. The battery may have a kWh value of more than 10 kWh, preferably more than 15 kWh, more preferably more than 20 kWh. The battery may have a kWh value up to 500 kWh, preferably 300 kWh more preferably 200 or 100 kWh. The kWh value may lie between any of these values such as between 10 and 500, 15 and 300 or between 20 and 200 kWh.

A least one component of the battery to be recycled may include a single component of the battery or multiple components of the battery. The at least one component of the battery may refer to any component of the battery, any combination of components of the battery or the battery with all its components. Component of the battery may be anode active material, cathode active material, electrolyte composition, anode element, cathode element, separator, electrolyte, battery cell, battery module, packaging material, battery management module, cooling module, high-voltage module, wiring, battery housing or the like.

Recycling of batteries as used herein may include any recycling step from end of life of the battery to any recyclate usable to produce new batteries. The new product produced from recyclate may be different product type than the battery to be recycled. The new product produced from recyclate may be a new battery produced from recyclate as provided by the battery or at least one of its component to be recycled. The recyclate may contain metals, such as transition metals or other precious metals. The new product may be material such as

cathode active material produced from recycled black mass. Recycling steps may include collecting, discharging, dismantling, sorting, mechanical treatment, chemical treatment, thermal treatment or any other steps for transforming used material of the battery into recycled raw materials. Recycling of batteries may include the recycling of one or more component(s) of the battery, such as cathode element or cathode active material. Recycling of materials contained in batteries may include one or more recycling process(es) for transforming used material into recycled raw materials Recycling of batteries may refer to one or more recycling process(es) for transforming used material of batteries into recycled raw materials. The recycled raw materials may be used for producing new materials with recycled content. The new materials with recycled content may be used for producing batteries.

The plant as used herein may include any plant processing batteries, battery components or battery materials. Such processing may include recycling or production. The plant may perform one or more process steps, such as collecting, discharging, dismantling, sorting, mechanical treatment, chemical treatment, thermal treatment, production of batteries, production of battery components, production of materials or any other steps for transforming used material of used batteries into recycled raw materials or new batteries. Recycling instructions may include collecting, sorting, transport, storing or other process instructions or any combinations thereof that related to recycling processes. Such recycling instructions may be provided to one or more system(s) configured to monitor and/or control process steps such as collecting, sorting, transport, storing or other process instructions or any combinations thereof.

Material identifier package may include any data structure that relates battery identifiers according to at least one material configuration that is processable or to be processed by at least one recycling plant. Material identifier package may include one or more battery identifier(s) associated with the at least one material configuration processable or to be processed by at least one recycling plant. Material identifier package may include a gathering of battery identifiers associated with at least one or more component(s) of the battery to be recycled and with the at least one material configuration processable or to be processed by at least one recycling plant. Material identifier package may include any data for collecting, sorting, transporting, storing, processing or providing batteries for subsequent recycling step(s). Material identifier package may comprise battery identifiers and corresponding material configuration data associated with the material configuration that is processable or to be processed by at least one recycling plant. Material identifier package may comprise battery recycling classification data or instructions. Material identifier package may further include operation data indicating process requirements for the material configuration and/or battery location data. In

other words, material identifier package may include data because of which a choice or allocation of batteries or components to be recycled to at least one respective recycling plant may be made.

Battery identifier may include any identifier uniquely associated with at least one component of the battery to be recycled. The battery identifier may include an identifier associated with the battery and/or at least one component of the battery. The battery identifier may include more than one identifier associated with the battery and/or at least one component of the battery. The battery identifier may include any unique identifier uniquely associated with a data owner and material configuration data associated with at least one component of the battery to be recycled. The battery identifier may include or relate to one or more decentral identifier(s). The decentral identifier may include one or more Universally Unique Identifier(s) (UUID) or a Digital Identifier(s) (DID). The decentral identifier may be issued by a central or decentral identity issuer. Via the decentral identifier and its unique association with the data owner and material configuration data access to the material configuration data may be controlled by the data owner. This contrasts with central authority schemes, where identifiers are provided by the central authority and access to the data is controlled by such central authority. Decentral in this context refers to the usage of the identifier as controlled by the data owner. The data owner of material configuration data may be the material producer, a component producer using the material produced by the material producer for producing one or more component(s) and/or a battery producer using the material produced by the material producer for producing one or more battery(s). The data owner for material identifier packages and/or recycled material data may be one or more recycling system(s) and/or one or more plant(s), such as a recycler using end-of-life batteries to produce recycled material e.g. black mass, a recycler using black mass to produce recyclate e.g. transition metals, a material producer, a component producer using the material produced by the material producer for producing one or more component(s) and/or a battery producer using the material produced by the material producer for producing one or more battery(s). The data owner for plant data, plant assignment data and/or operation data may be one or more recycling system(s) and/or one or more plant(s), such as a recycler using end-of-life batteries to produce recycled material e.g. black mass, a recycler using black mass to produce recyclate e.g. transition metals, a material producer, a component producer using the material produced by the material producer for producing one or more component(s) and/or a battery producer using the material produced by the material producer for producing one or more battery(s). The decentral identifier may be connected to a digital representation of material configuration data. The digital representation may include a representation for accessing the material configuration data or parts thereof. The decentral identifier may be connected to

authentication information and/or authorization information. The decentral identifier may be connected to further battery data.

Battery identifier element may include any physical arrangement that associates the battery identifier with the battery or at least one component of the battery. The battery identifier element may comprise a passive or active element, e.g. QR-code, RFID-tag, but is not limited thereto. The battery identifier element may be a physical identifier physically connected to the battery or at least one component of the battery. The identifier element may include markers embedded in materials, a bar code, a QR-Code, a tag like a RFID tag or similar physical arrangement that allows to digitally identify the battery or at least one component of the battery.

Material configuration data may include the material configuration of the battery or the battery component. The material configuration data may be associated with at least one material type, at least one material property and/or at least one chemical composition associated with at least one component of the battery to be recycled. Material configuration data may include material type, material property and/or chemical composition of the material used to produce the battery or component of the battery. Material type, material property and/or chemical composition may specify the material configuration at least in part. Material type may include material specifications like plastics, composite material, metal containing material or the like as present in end-products, intermediate products, by-products, or raw material but is not limited thereto. Material properties may include physical material properties, e.g. thermodynamic, mechanic, electrodynamic, optic and acoustic material properties, and chemical material properties, e.g. Standard electrode potential and electronegativity, but are not limited thereto. The chemical composition may correspond to at least one constituent included in the composition. For instance, the chemical composition may be specified by absolute or relative amount of one or more element(s), chemical compound(s) or constituent(s) that are contained in the material.

Material configuration data may be associated with the material configuration of one or more component(s) of the battery. Material configuration data may specify the material configuration on component basis. For instance, material configuration data may specify at least partially the chemical composition of the electrode active material, the anode active material, the electrolyte or the housing. The material configuration data may be associated with the chemical composition of the electrode active material, e.g. the cathode active material. The battery identifier may be associated with any component including the electrode active material. The component may be the electrode element, such as the anode element or the cathode element,

the cell, the cell module or the battery. The battery identifier may be connected or related to one or more identifier(s) related to the material used to produce the battery or at least one component of the battery.

In one embodiment the material configuration data is provided for access on providing the material for production of the product, on providing the material for at least one component of the battery and/or on production of the material used to produce the battery or the at least one component of the product. The material configuration data may be accessed on recycling of the battery or component containing the material. The battery identifier may be associated with the battery to be recycled or at least one component of the battery to be recycled. The relation of the battery identifier and the product, component or material may be provided prior or on production of the product. The battery identifier may relate to one or more decentral identifiers, wherein at least one decentral identifier is associated with the material used to produce the battery or at least one component of the product. The battery identifier may relate to a relationship representation. The relationship representation may relate the battery identifier to the identifier of the material used to produce the battery or at least one component of the product. The relationship representation may reflect the physical connection of the material and the battery or in other words the use of the material to produce the product. This way the battery identifier and the identifier associated with the material used to produce the battery or at least one component of the battery may be connected or related. On receipt of the battery identifier, the identifier associated with the material used to produce the battery or at least one component of the battery may be determined. Material configuration data may be retrieved based on the identifier associated with the material used to produce the battery or at least one component of the product, in particular from the material producer.

The battery identifier may be uniquely associated with a data owner and/or material configuration data associated with the material used to produce the battery or component, the battery or at least one component of the battery e.g. as provided prior or on production of the material, the battery or at least one component of the product. The material configuration data may specify the material configuration of the material used to produce the battery or at least one component of the product. Prior or on production of the material, the battery or at least one component of the battery may include any point leading to production of the material, the battery or the at least one component of the product. Prior or on production of the material, the battery or at least one component of the battery may include on production of the material, on providing

the material to produce the battery or the at least one component of the battery or on production of the battery or the at least one component of the product.

The material configuration data may be provided for access on providing the material for production of the product. The material configuration data may be accessed on recycling of the battery or at least one component of the battery containing the material. The material configuration data may be accessed via a digital representation, such as a pointer, a link or a link pointing, to material configuration data. The material configuration data may be accessed on recycling, for example by reading the battery identifier, by determining the identifier associated with the material via the battery identifier e.g. through the relationship representation and by gathering at least the digital representation associated with the identifier associated with the material. Via the digital representation linked to the identifier associated with the material used to produce the battery or the component of the product, material configuration data may be accessed. The material configuration data associated with the material used to produce the battery or the component of the battery may be accessed or requested from a decentral computing node associated with the recycling system(s). The material configuration data associated with the material used to produce the battery or the component of the battery may be provided or obtained from the decentral computing node associated with the producer producing or using the material, such as the material producer, the battery producer and/or the component producer. The access to the material configuration data may be based on the decentral identifier(s) of the material used to produce the battery or the component of the product. The material configuration data may be provided or transferred by at least one decentral computing node associated with a producer producing or using the material, such as the material producer, the battery producer and/or the component producer. The material configuration data may be provided to or received by the decentral computing node associated with the recycling system(s).

In one embodiment the material configuration data relates to the chemical composition of the electrode active material. The material configuration data may specify at least one constituent of the chemical composition of the electrode active material, such as transition-metal containing constituents or precious-metal containing constituents. The at least one battery identifier may relate to the component of the battery, for which the material configuration data specifies the material configuration. The at least one battery identifier may relate to a first component of the battery including a second component, for which the material configuration data specifies the material configuration. The at least one battery identifier may relate to the electrode active material with material configuration, which the material configuration data specifies. The at least

one battery identifier may relate to the battery, the cell, the cell pack or the electrode element including electrode active material with material configuration, which the material configuration data specifies. The at least one battery identifier may relate to the battery or at least one component of the battery and an identifier associated with the material used to produce the battery or the at least one component of the battery may be related to the at least one battery identifier.

In one embodiment the material configuration data or recycled material data is provided by computer-executable instructions running in an at least partially decentral or decentral computing environment, wherein the computer-executable instructions access the material configuration data based on the battery identifier or the recycled material data based on the packaged battery identifiers or the package identifier. The material configuration data may be provided on end-of-life of the battery or the at least one component of the battery. The recycled material data may be provided at any stage of the recycling process of the battery or the at least one component of the battery. By way of identity-based access, a decentral data service may be used for flexible and secure access to the recycled material data, such as the recycled material data or material configuration data, controlled by the data owner. In such embodiment the material configuration data may be provided by a storage environment under control of the material data provider, such as the material producer, recycler or recycling system(s). Such storage environment may by accessible by computer-executable instructions based on an authentication and/or authorization process or protocol. The computer-executable instructions accessing the material configuration data based on the battery identifier may initiate data transfer or may initiate data processing followed by transfer of the processing result. Processing may for instance include determining material identifier package. The computer-executable instructions accessing the recycled material data based on the packaged product identifiers and/or the package identifier may initiate data transfer. The material data provider may be the provider of the physical material or owner of the material data. For material configuration data, the material data provider may be the material producer. The material configuration data may be provided by a computing node of a decentral computing environment, wherein the computing node may be associated with the material producer. For recycled material data, the material data provider may be one or more recycling system(s). The recycled material data may be provided by a computing node of a decentral computing environment, wherein the computing node may be associated with one or more recycling system(s). The material data provider may be a third party controlling the material data on behalf of the provider of the physical material provider or material data owner. This enables the owner of material data to control usage of material configuration data. In addition, secure data sharing or exchanging across participants of the recycling or production chain can be enabled.

In one embodiment the at least one material identifier package includes one or more battery identifier(s) and corresponding material configuration data associated with the battery or at least one component of the battery to be recycled. In one embodiment the at least one material identifier package includes material composition data associated with the recycled battery material as produced from the battery or the at least one recycled component of the battery, wherein the material composition data is determined from the battery identifiers and their corresponding material configuration data. For instance, the material identifier package may include at least one package identifier and corresponding material composition data associated with the recycled battery material as produced from the battery or the at least one recycled component of the battery. The material composition data may be determined from the battery identifiers packaged and their corresponding material configuration data. Further for instance, the material identifier package may include one or more battery identifier(s) and material composition data as determined from their corresponding material configuration data. Recycled material data may include at least one package identifier and corresponding material composition data associated with the recycled material as produced from the product or at least one recycled component of the product. In one embodiment the at least one material identifier package includes material quantity data associated with the recycled material as produced from the product or the at least one recycled component of the product, wherein the material quantity data is determined from the product identifiers and their corresponding material configuration data. Material quantity data may include number, mass, weight or volume of products, components or material to be recycled.

The at least one material identifier package may be associated with at least one material configuration processable or to be processed by at least one plant, such as a recycling or production plant. In the context of the at least one material configuration processable or to be processed by at least one plant, the plant may perform at least one process, such as recycling or production process, for one or more material configuration(s). The at least one process may be predefined, such as a pre-defined recycling or production process. The at least one material configuration processable or to be processed by at least one plant may refer to material configuration(s) processable or to be processed by at least one plant in one or the same process run. The at least one material configuration processable or to be processed by at least one plant may refer to material configuration(s) processable or to be processed by the same plant or the same plant type. The at least one material configuration processable by at least one plant may include material configuration(s) processable together. The at least one material configuration processable by at least one plant may include material configuration(s)

processable together in one plant. The at least one material configuration processable by at least one plant may include material configuration(s) processable together in one or the same process run. The at least one material configuration processable by at least one plant may include material configuration(s) assignable to one plant or process.

In one embodiment determining the at least one material identifier package includes providing classification instructions running in an at least partially decentral computing environment, wherein the classification instructions gather battery identifiers according to material configuration(s) processable or to be processed by at least one plant.

In one embodiment determining the at least one material identifier package includes classification according to classification instructions providing the material configuration(s) processable or to be processed by at least one plant. The classification may be performed according to classification instructions relating the material configuration(s) processable or to be processed by at least one plant to at least one battery identifier.

In one embodiment determining the at least one material identifier package includes providing classification instructions running in an at least partially decentral or decentral computing environment, wherein the classification instructions gather battery identifiers according to material configuration(s) processable or to be processed by at least one plant such as at least one recycling plant. Classification instructions may include gathering of battery identifiers based on the material configuration data and the material configuration(s) processable or to be processed by at least one plant such as at least one recycling plant. Classification instructions may include classes of material configuration(s) processable or to be processed by at least one plant and gathering battery identifiers according to the classes of material configuration(s). Classification instructions may initiate matching of the material configuration provided by the material configuration data with material configuration(s) processable or to be processed by at least one plant. Classification instructions may relate material configuration data to plant identifier(s) and corresponding material configuration(s) processable or to be processed by the plant. The classification instructions may be dynamically adjustable based on operation data, in particular process data indicative of current operations of the at least one plant.

By way of identity-based classification, a classification service may be used for flexible and secure classification. In such embodiment the material configuration data may be provided by a

storage environment under control of the material data provider. Such storage environment may by accessible by classification instructions based on an authentication and/or authorization process or protocol. The classification instructions accessing the material configuration data based on the battery identifier may initiate classification followed by transfer of the classified result. The classification instructions may be triggered by one or more recycling system(s) on recycling of the product or at the end-of-life stage of the product. The classification instructions may access the material configuration data via the product identifier as provided by a material producer. The classification instructions may transfer the classification result to one or more recycling system(s). The material configuration data provider may be the provider of the physical material or owner of the material configuration data. The material configuration data provider may be a third party controlling the material configuration data on behalf of the provider or producer of the physical material provider or material configuration data owner. This enables the owner of material configuration data to control usage of material configuration data while not sharing such data with recycling system(s). In addition, secure data sharing or exchanging across participants of the recycling or production chain can be enabled.

In one embodiment the at least one battery identifier is provided from a sensor reading a battery identifier element, wherein the battery identifier element is physically connected to the at least one component of the battery to be recycled. The identification element may be physically connected to the battery, e.g. the battery housing, uniquely identifying the battery. The identification element may be physically connected to any component of the battery, e.g. the battery cell or module, uniquely identifying the component of the battery.

Further comprised may be the step of operating the recycling process by providing the material identifier package for controlling and/or monitoring recycling system(s). The identifier package may include a package identifier, such as a decentral identifier. The identifier package may be provided to the decentral computing node associated with one or more recycling system(s). The identifier package may be generated by the decentral computing node associated with one or more recycling system(s). The decentral computing node associated with one or more recycling system(s) may control and/or monitor the one or more recycling system(s). Operating based on the at least one material identifier package may include operating the battery recycling process for recycling of materials contained in products associated with the at least one battery identifier. Operating based on the at least one material identifier package may include operating the recycling process by providing collecting, sorting, transporting, storing and/or recycling instructions configured to monitor and/or control recycling systems. Operating based on the at least one material identifier package may include operating the recycling process by providing

collecting, sorting, transporting, storing and/or recycling instructions configured to monitor and/or control collecting, sorting, transport, storing and/or recycling or the respective systems. Operating based on the at least one material identifier package may include operating the recycling process by collecting, sorting, transporting, storing and/or recycling materials contained in products associated with at least one battery identifier. Further comprised may be the step of operating the recycling process preferably by gathering battery identifiers to provide the material identifier package to recycling system(s) to control and/or monitor such system(s). The battery recycling process for recycling of materials contained in products associated with the at least one battery identifier may be operated based on the at least one material identifier package. The battery recycling process may be operated by providing the material identifier package for controlling and/or monitoring recycling system(s). The battery recycling process may be operated by providing collecting, sorting, transporting, storing and/or recycling instructions configured to monitor and/or control collecting, sorting, transport, storing and/or recycling. The battery recycling process may be operated by collecting, sorting, transporting, storing and/or recycling materials contained in products associated with at least one battery identifier. Recycling system(s) may include sorting, collector, transport and/or storing system. The system(s) may be controlled and/or monitored based on the material identifier package. Further comprised may be the step of sorting, collecting, transporting and/or storing recycled material based on the material identifier package, preferably based on sorting, collecting, transporting and/or storing instructions based on material identifier package(s). The sorting, collector, transport and/or storing system may be monitored and/or controlled and/or operated based on the material identifier package(s), preferably based on respective instructions generated from material identifier package(s). In the recycling process the products or components may be packaged by providing material identifier package according to the material configuration of the products or components. The recycled material may be provided by mechanical, thermal and/or chemical recycling plants.

In one embodiment further comprising the step of providing sorting and/or collecting instructions based on or generated from the provided material identifier package, wherein the sorting and/or collecting instructions comprise instructions for sorting and/or collecting the at least one component of the battery to be recycled based on the material configuration of the at least one component of the battery to be recycled.

Disclosed is also a method and corresponding apparatus for providing sorting and/or collecting instructions based on material identifier package. Any method steps disclosed in conjunction with such method may be performed by the corresponding apparatus comprising one or more

computing nodes; and one or more computer-readable media having thereon computer-executable instructions that are structured such that, when executed by the one or more computing nodes. For generating and/or providing such instructions individual steps may be performed in combination with the methods, systems, apparatuses or computer elements for providing material identifier package or for operating the recycling process.

Comprised may be the step of providing material identifier package comprising at least one battery identifier related to at least one material identifier package, wherein the at least one material identifier package is associated with at least one material configuration processable or to be processed by at least one plant.

Further comprised may be the step of generating sorting instructions based on the material identifier package, wherein the sorting instructions relate battery identifiers provided by a sensor reading the battery identifier element to material configuration(s) processable or to be processed by at least one plant. Preferably the sorting instructions relate battery identifiers provided by a sensor reading to the at least one material identifier package.

Further comprised may be the step of generating collecting instructions based on the material identifier package, wherein the collecting instructions relate battery identifiers provided by a sensor reading a battery identifier element to the at least one material identifier package.

Further comprised may be the step of providing collection point data signifying the collection point of the at least on component of the battery. The collection point data may be included in the material identifier package.

Further comprised may be the step of providing transporting and/or storing instructions based on or generated from the provided material identifier package. The transport and/or storing instructions may comprise information on how the at least one component of the battery is to be transported and/or stored. The transport and/or storing instructions may relate to the location and/or quantity of the products or components of the product.

Disclosed is also a method and corresponding apparatus for providing transport and/or storing instructions based on material identifier package. Any method steps disclosed in conjunction with such method may be performed by the corresponding apparatus comprising one or more computing nodes; and one or more computer-readable media having thereon computer-executable instructions that are structured such that, when executed by the one or more computing nodes. For generating and/or providing such instructions individual steps may be performed in combination with the methods, systems, apparatuses or computer elements for providing material identifier package or for operating the recycling process.

Further comprised may be the step of providing operation data associated with at least one operation property of the plant. The operation data may relate to at least one plant identifier. The operation data may include corresponding plant location data associated with a plant location of the plant, capacity data associated with a capacity of the plant, process data associated with one or more process(es) of the plant and/or material processing data associated with at least one material configuration processable or to be processed by the plant. The operation data may relate to at least one static operation property of the plant and/or at least one dynamic operation property of the same plant or plant type. The latter allows for real time perspective on capacities, process data and/or material processing data. Plants can be matched based on real-time information allowing for more efficient and targeted use of plant resources in the recycling process.

Further comprised may be the step of providing collection point data signifying the collection point of the at least on component of the battery. The collection point data may be included in the material identifier package.

Further comprised may be the step of generating transport instructions based on the collection point data and the operation data, particularly plant location data. Based on such data one or more transport route(s) may be determined. The collection point data may signify the starting point for transport and the plant location data may signify the destination point of the transport route.

Further comprised may be the step of determining storing instructions based on operation data, in particular capacity data and a quantity relating to the amount of material associated with material configuration(s) processable or to be processed by at least one plant or a quantity

related to the amount of material with material configuration(s) processable or to be processed by at least one plant.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, the present disclosure is further described with reference to the enclosed figures:

Fig. 1	illustrates schematically a battery with a battery identification element.
Fig. 2	illustrates schematically a battery component with an identification element.
Figs. 3a,b	illustrate example embodiments of a centralized and a decentral computing environment with computing nodes.
Fig. 3c	illustrates an example embodiment of a distributed computing environment.
Fig. 3d	illustrates an example environment for making data accessible for processing.
Fig. 4	illustrates a flow diagram of an example method for providing material identifier package usable for the recycling of batteries, in particular for operating a recycling process.
Fig. 5	illustrates an example embodiment of a flowchart for providing material identifier package usable for recycling of batteries, in particular for operating the recycling process.
Fig. 6	illustrates an example data structure based on decentral identifiers for battery.

Fig. 7 illustrates another example data structure based on decentral identifiers for battery packages.

Fig. 8 illustrates an example embodiment of a flowchart for providing plant assignment data usable for processing recycled battery material, in particular for operating a recycling process.

Fig. 9 illustrates an example embodiment of a flowchart for providing plant assignment data usable for processing recycled battery material, in particular for operating a recycling process.

Fig. 10 illustrates an example embodiment of a flowchart for assigning plants to operate a recycling process.

Figs. 11-13 illustrates an example data structures based on decentral identifiers for battery packages or recycled material packages in connection with plant identifiers.

Fig. 14 illustrates an example system for operating the recycling process in the recycling chain of a battery.

Fig. 15 illustrates an example of the recycling chain for batteries.

Fig. 16 illustrates an example flowchart of a method for providing a recyclate feed content for producing at least one component of the battery.

Fig. 17 illustrates another example of the method for providing a recyclate feed content for producing at least one component of the battery based on availability data and optionally including the selection of a production plant.

Fig. 18 illustrates another example of the method for providing a recyclate feed content for producing at least one component of the battery including chemical performance check.

Fig. 19 illustrates another example of the method for providing a recyclate feed content for producing at least one component of the battery including emission target check and optionally plant selection.

Figs. 20, 21, 22 depict embodiments of a user interfaces for entering recycling quotas, chemical performance parameters or emission targets.

DETAILED DESCRIPTION OF EMBODIMENT

The following embodiments are mere examples for implementing the methods, the systems or the computer elements disclosed herein and shall not be considered limiting.

Fig. 1 illustrates schematically a battery 10 with a battery identification element 12, 14.

The battery 10 may comprise a battery management system 16 and a plurality of battery cells 18 arranged inside a battery housing 20. The battery cells 18 may be arranged in battery packs or modules comprising multiple battery cells 18. The battery cell 10 may comprise an electrolyte 22, an anode element 24, a cathode element 26, and/or a separator 28.

Depending on application, batteries comprise different material compositions for the different components. For instance, the battery may be a lithium-ion battery. The cathode elements 26 may include active material coated on a collector foil such as aluminum or copper foil. Further binders, polyvinylidene fluoride (PVDF) and/or carbon as conducting agents may be contained. Cathode active materials may contain layered oxides (LiMO2 with M=Co, Ni, Mn, Al such as LCO (LiCoO2), NCM (LiNixMnyCozO2), NCA (LiNixCoyAlzO2)), spinels (LiM2O4 with M=Mn, Ni such as LMO (LiMnO4)) or phosphates (LiMPO4 with M= Fe, Mn, Co, Ni such as LiFePO4).

The anode element 24 may include anode active material coated on collector foil such as aluminum or copper foil. The active material may contain artificial graphite, natural graphite or compositions thereof. The active material may include silicon, SiO2, lithium titanate (LTO) or combinations thereof. The active material may contain binders such as styrene-butadiene rubber (SBR), polymeric thickener like carboxylmethyl cellulose (CMC) and carbonates as conducting agent.

The electrolytes may comprise salts, solvents and additives such as carbonates, esters or ethers to provide conductivity. Mixtures of cyclic carbonates such as ethylene carbonate (EC) or propylene carbonate (PC) with open chained carbonates such as dimethyl carbonate (DMC) may be included. As conducting salt lithium hexafluorophosphate (LiPF6), lithium bis(trifluormethyl)sulfonylimid (LiTFSI) and its derivates (e.g., lithium bis(fluorosulfonyl) imide (LiFSI)) or lithium [tris(pentafluorethyl)-trifluorphosphate] (LiFAP), lithium 4,5-dicyano-2-trifluoromethyl-imidazolide (LiTDI), lithium bis(oxalate)borate (LiBOB)), ethyl methyl carbonate (EMC), and/or diethyl carbonate (DEC) may be used.

Separators may divide the space between the electrodes and are permeable for ions. Separator types include: microporous membranes, ceramic-coated separators, non-woven mats, solid inorganic or polymeric electrolytes. Polyolefin-based membranes coated e.g., with PVDF or ceramics may be used.

The battery identification element 12, 14 may be physically associated with the battery 10. The identification element 12, 14 may be physically attached to the battery housing or be part of the battery management system 16. The identification element 12, 14 may be arranged inside or outside the battery housing 20. The identification element 12, 14 may be a passive identification element 14. The passive element 14 may be arranged on the outer surface of the battery housing 20. The passive element 14 may be based on markers embedded into the material. The passive element 14 may include a printed code such as a bar code or a QR code. The identification element 12, 14 may be an active identification element 14. The active element 14 may be a transmitter or transceiver tag, such as an RFID tag enabling communication through e.g. NFC, Bluethoth, Zigbee or other suitable near- to mid-range communication protocols. The identification element 14 may be part of the battery management system 16 e.g. the digital battery identifier may be stored in the battery management system 16 and may be retrieved from the battery management system through communication protocols such as NFC, Bluethoth, Zigbee or other suitable near- to mid-range communication protocols.

The battery identification element 12, 14 may be associated with a digital battery identifier. The digital battery identifier may be unique for the battery. The digital battery identifier may be further associated with data relating to the battery identified. Such data may include any data collected during the production or lifetime of the battery 10. For instance, such data may include material data such as material configuration data collected during production of the battery or monitoring data collected during use of the battery may be by associated with the digital battery identifier. Data relating to the battery identified or part(s) thereof may relate to or include the material configuration data. The material configuration data may be controlled by one or more material producer(s) e.g. via authentication and/or authorization mechanisms. The material configuration data may be controlled by the one or more material producer(s). The one or more material producer(s) may provide respective material configuration data for access by participant nodes of the decentral computing environment. Data relating to the battery or part(s) thereof may be stored in data bases associated with participant nodes of the decentral computing environment, in particular associated with producers of the battery, the components or the material or users of the battery. The participant node(s) storing the data relating to the battery identified or part(s) thereof may provide access to other participant node(s) e.g. via peer-to-peer communication including authentication and/or authorization mechanisms. The data relating to the battery identified or parts thereof may relate to or include the material configuration data associated with the cathode element, such as the cathode active material, the anode element, the separator and/or the electrolyte. For example, the material configuration data may be associated with the electrode active material. Such data may be provided by the material producer for access by participant node(s) of the decentral computing environment, e.g. via peer-to-peer communication including authentication and/or authorization mechanisms.

The digital battery identifier may include or be associated with at least one decentral identifier. The decentral identifier may comprise any unique identifier uniquely associated with the data owner and the identified battery 10. Including a data point may relate to a data package including such data point and/or data digitally linked to or in any way associated with the data point to virtually or digitally form a data package. The decentral identifier may comprise any unique identifier uniquely associated with the data relating to the battery identified, such as material configuration data, and the identified battery 10. The decentral identifier may include or relate to one or more Universally Unique Identifier(s) (UUID) or one or more Digital Identifier(s) (DID). The decentral identifier may be issued by a central or decentral identity issuer. The decentral identifier may include authentication information for authentication of the data relating to the identified battery 10. Via the decentral identifier and its unique association with the battery

10 identified access to the data relating to the identified battery may be controlled by at least one data owner. This contrasts with central authority schemes, where identifiers are provided by central authority and access to data is controlled by such central authority. Decentral in this context refers to the usage of the identifier as controlled by any data owner. The data may be hosted in a database associated or under control of the data owner. The identification element 12, 14 may be configured to provide the digital battery identifier for accessing data relating to the identified battery.

The decentral identifier may include one or more identifier(s) used in the decentral computing environment and allowing for data exchange via the decentral computing environment, such as the peer-to-peer communication channel. Data exchange may include discovery of the decentral identifier for participant nodes of the decentral computing environment, authentication of participant nodes of the decentral computing environment and/or authorization of data transfers via a peer-to-peer communication between participant nodes of the decentral computing environment.

The data owner may comprise any entity generating data, particularly data relating to the battery identified. The generating node may be coupled to the entity owning physical products from or for which data, particularly, the data relating to the battery identified, is generated. The data, particularly the data relating to the battery identified, may be generated by a third-party entity on behalf of the entity owning physical products from or for which data is generated. The data owner may be the producer of the material, component contained in the battery or the battery, such as the material producer, the component producer or product producer. Via the decentral identifier and its unique association with the data owner and data relating to the battery identified access to the respective data may be controlled by the data owner. The data relating to the battery identified may be accessible for the data owner. The data owner may hence directly or indirectly own or control the data relating to the battery identified. The data relating to the battery identified may be stored in a data base of or associated with the data owner. The data relating to the battery identified may be stored in a data base accessible by the data owner. The data owner may control access to the data relating to the battery identified via the data providing service of the data owner. The data owner may control access to the data relating to the battery identified. The data relating to the battery identified may be associated with the data owner. The data owner may be the owner or controller of the data relating to the battery identified or the data relating to the battery identified owner. The data relating to the battery identified may be stored in a data base of or under control by the data owner. In this sense, the data owner may relate to the entity having access to the data relating to the battery identified or parts thereof and controlling access by data consuming services of the decentral computing environment to the data relating to the battery identified or parts thereof.

In particular, the digital battery identifier may relate to the material configuration data specifying the material configuration of one or more component(s) of the battery. The digital battery identifier may be associated with the battery 10 and the material configuration data may specify the material configuration of one or more component(s) of the battery 10.

Fig. 2 illustrates schematically a battery component 30 with an identification element 32, 34.

The battery component 30 may include one or more sub-components of the battery 10. The sub-component may include the battery management system 16, the battery housing 20, the battery module or pack with a plurality of battery cells 22, the battery cell 22 or combinations of such sub-components. The battery component identification element 32, 34 may be associated with the battery component 30. The identification element 32, 34 may be physically attached to the battery component 30. The identification element 32, 34 may be arranged inside or outside the battery component 30. The identification element 32, 34 may be a passive or an active identification element 32, 34 as described in the context of Fig. 1. The battery identification element 32, 34 may be associated with a digital battery component identifier. The digital battery identifier may include at least one decentral identifier associated with the identified battery component 30 as described in the context of Fig. 1. In particular, the identification element 32, 34 may be configured to provide the digital battery component identifier for accessing data relating to the identified battery component, such as material configuration data as e.g. described in the context of Fig. 1. The battery identifier may relate to the component 30, for which the material configuration data specifies the material configuration.

Figs. 3a to 3c illustrate different computing environments, central, decentral and distributed. The methods, apparatuses, systems, uses, computer elements of this disclosure may be implemented in decentral or at least partially decentral computing environments. Providing, determining or processing of data may be realized by different computing nodes, which may be implemented in a central, a decentral or a distributed computing environment.

Figs. 3a,b illustrate example embodiments of a central and a decentral computing environment with computing nodes. Fig. 3c illustrates an example embodiment of a distributed computing environment. Fig. 3d illustrates an example environment for making data accessible. Such environment may be implemented according to standard based on International Data Space

(IDS) or Digital Identifiers from W3C. Such implementations aid to make data associated with decentral identifiers from material providers accessible to data consumers.

Fig. 3a illustrates an example embodiment of a centralized computing system 100 comprising a central computing node 101 (filled circle in the middle) and several peripheral computing nodes 101.1 to 101.n (denoted as filled circles in the periphery). The term “computing system” is defined herein broadly as including one or more computing nodes, a system of nodes, network nodes or combinations thereof. The term “computing node” is defined herein broadly and may refer to any device or system that includes at least one physical and tangible processor, and/or a physical and tangible memory capable of having thereon computer-executable instructions that are executed by a processor. Computing nodes are now increasingly taking a wide variety of forms. Computing nodes may, for example, be handheld devices, production facilities, sensors, monitoring systems, control systems, appliances, laptop computers, desktop computers, mainframes, data centers, or even devices that have not conventionally been considered a computing node, such as wearables (e.g., glasses, watches or the like). The memory may take any form and depends on the nature and form of the computing node.

In this example, the peripheral computing nodes 101.1 to 101.n may be connected to one central computing system (or server). In another example, the peripheral computing nodes 101.1 to 101.n may be attached to the central computing node via e.g. a terminal server (not shown). The majority of functions may be carried out by, or obtained from the central computing node (also called remote central location). One peripheral computing node 101.n has been expanded to provide an overview of the components present in the peripheral computing node. The central computing node 101 may comprise the same components as described in relation to the peripheral computing node 101.n.

Each computing node 101, 101.1 to 101.n may include at least one hardware processor 102 and memory 104. The term “processor” may refer to an arbitrary logic circuitry configured to perform basic operations of a computer or system, and/or, generally, to a device which is configured for performing calculations or logic operations. In particular, the processor, or computer processor may be configured for processing basic instructions that drive the computer or system. It may be a semi-conductor based processor, a quantum processor, or any other type of processor configures for processing instructions. As an example, the processor may be or may comprise a Central Processing Unit ("CPU"). The processor may be a (“GPU”) graphics processing unit, (“TPU”) tensor processing unit, ("CISC") Complex Instruction Set Computing

microprocessor, Reduced Instruction Set Computing ("RISC") microprocessor, Very Long Instruction Word ("VLIW") microprocessor, or a processor implementing other instruction sets or processors implementing a combination of instruction sets. The processing means may also be one or more special-purpose processing devices such as an Application-Specific Integrated Circuit ("ASIC"), a Field Programmable Gate Array ("FPGA"), a Complex Programmable Logic Device ("CPLD"), a Digital Signal Processor ("DSP"), a network processor, or the like. The methods, systems and devices described herein may be implemented as software in a DSP, in a micro-controller, or in any other side-processor or as hardware circuit within an ASIC, CPLD, or FPGA. It is to be understood that the term processor may also refer to one or more processing devices, such as a distributed system of processing devices located across multiple computer systems (e.g., cloud computing), and is not limited to a single device unless otherwise specified.

The memory 104 may refer to a physical system memory, which may be volatile, non-volatile, or a combination thereof. The memory may include non-volatile mass storage such as physical storage media. The memory may be a computer-readable storage media such as RAM, ROM, EEPROM, CD-ROM, or other optical disk storage, magnetic disk storage, or other magnetic storage devices, non-magnetic disk storage such as solid-state disk or any other physical and tangible storage medium which can be used to store desired program code means in the form of computer-executable instructions or data structures and which can be accessed by the computing system. Moreover, the memory may be a computer-readable media that carries computer- executable instructions (also called transmission media). Further, upon reaching various computing system components, program code means in the form of computer-executable instructions or data structures can be transferred automatically from transmission media to storage media (or vice versa). For example, computer-executable instructions or data structures received over a network or data link can be buffered in RAM within a network interface module (e.g., a “NIC”), and then eventually transferred to computing system RAM and/or to less volatile storage media at a computing system. Thus, it should be understood that storage media can be included in computing components that also (or even primarily) utilize transmission media.

The computing nodes 101, 101.1…101.n may include multiple structures 106 often referred to as an “executable component, executable instructions, computer-executable instructions or instructions”. For instance, memory 104 of the computing nodes 101, 101.1…101.n may be illustrated as including executable component 106. The term “executable component” or any equivalent thereof may be the name for a structure that is well understood to one of ordinary

skill in the art in the field of computing as being a structure that can be software, hardware, or a combination thereof or which can be implemented in software, hardware, or a combination. For instance, when implemented in software, one of ordinary skill in the art would understand that the structure of an executable component includes software objects, routines, methods, and so forth, that is executed on the computing nodes 101, 101.1…101.n, whether such an executable component exists in the heap of a computing node 101, 101.1…101.n, or whether the executable component exists on computer-readable storage media. In such a case, one of ordinary skill in the art will recognize that the structure of the executable component exists on a computer-readable medium such that, when interpreted by one or more processors of a computing node 101, 101.1…101.n (e.g., by a processor thread), the computing node 101, 101.1…101n is caused to perform a function. Such a structure may be computer-readable directly by the processors (as is the case if the executable component were binary). Alternatively, the structure may be structured to be interpretable and/or compiled (whether in a single stage or in multiple stages) so as to generate such binary that is directly interpretable by the processors. Such an understanding of example structures of an executable component is well within the understanding of one of ordinary skill in the art of computing when using the term “executable component”. Examples of executable components implemented in hardware include hardcoded or hard-wired logic gates, that are implemented exclusively or near-exclusively in hardware, such as within a field- programmable gate array (FPGA), an application-specific integrated circuit (ASIC), or any other specialized circuit. In this description, the terms “component”, “agent”, “manager”, “service”, “engine”, “module”, “virtual machine” or the like are used synonymous with the term “executable component.

The processor 102 of each computing node 101, 101.1…101.n may direct the operation of each computing node 101, 101.1…101.n in response to having executed computer-executable instructions that constitute an executable component. For example, such computer-executable instructions may be embodied on one or more computer-readable media that form a computer program product. The computer-executable instructions may be stored in the memory 104 of each computing node 101, 101.1…101.n. Computer-executable instructions comprise, for example, instructions and data which, when executed at a processor 101, cause a general purpose computing node 101, 101.1…101.n, special purpose computing node 101, 101.1…101.n, or special purpose processing device to perform a certain function or group of functions. Alternatively or in addition, the computer-executable instructions may configure the computing node 101, 101.1…101.n to perform a certain function or group of functions. The computer executable instructions may be, for example, binaries or even instructions that undergo some translation (such as compilation) before direct execution by the processors, such as intermediate format instructions such as assembly language, or even source code.

Each computing node 101, 101.1... 101.n may contain communication channels 108 that allow each computing node 101.1... 101.n to communicate with the central computing node 101, for example, a network (depicted as solid line between peripheral computing nodes and the central computing node in Fig. 25a). A "network" may be defined as one or more data links that enable the transport of electronic data between computing nodes 101, 101.1... 101.n and/or modules and/or other electronic devices. When information is transferred or provided over a network or another communications connection (either hardwired, wireless, or a combination of hardwired or wireless) to a computing node 101, 101.1... 101.n, the computing node 101, 101.1... 101.n properly views the connection as a transmission medium. Transmission media can include a network and/or data links which can be used to carry desired program code means in the form of computer-executable instructions or data structures and which can be accessed by a general-purpose or special-purpose computing nodes 101, 101.1... 101.n. Combinations of the above may also be included within the scope of computer-readable media.

The computing node(s) 101, 101.1 to 101.n may further comprise a user interface system 110 for use in interfacing with a user. The user interface system 110 may include output mechanisms 110A as well as input mechanisms 110B. The principles described herein are not limited to the precise output mechanisms 110A or input mechanisms 110B as such will depend on the nature of the device. However, output mechanisms 110A might include, for instance, displays, speakers, displays, tactile output, holograms and so forth. Examples of input mechanisms 110B might include, for instance, microphones, touchscreens, holograms, cameras, keyboards, mouse or other pointer input, sensors of any type, and so forth.

Figure 3b illustrates an example embodiment of a decentral computing environment 100' or a decentral network with several computing nodes 101.1' to 101.n' denoted as filled circles. The decentral network may include set protocols for authentication and/or authorization. In contrast to the centralized computing environment 100 illustrated in Fig. 3a, the computing nodes 101.1' to 101.n' of the decentral computing environment are not connected to a central computing node 101 and are thus not under control of a central computing node. Instead, resources, both hardware and software, may be allocated to each individual computing node 101.1'... 101.n' (local or remote computing system) and data may be distributed among various computing nodes 101.1'... 101.n' to perform the tasks. Thus, in a decentral system environment or decentral network, program modules may be located in both local and remote memory storage devices. One computing node 101' has been expanded to provide an overview of the

components present in the computing node 101'. In this example, the computing node 101' comprises the same components as described in relation to Fig. 3a.

Figure 3c illustrates an example embodiment of a distributed computing environment 103. In this description, "distributed computing" may refer to any computing that utilizes multiple computing resources. Such use may be realized through virtualization of physical computing resources. One example of distributed computing is cloud computing. "Cloud computing" may refer a model for enabling on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services). When distributed, cloud computing environments may be distributed internationally within an organization and/or across multiple organizations. In this example, the distributed cloud computing environment 103 may contain the following computing resources: mobile device(s) 114, applications 116, databases 118, data storage 120 and server(s) 122. The cloud computing environment 103 may be deployed as public cloud 124, private cloud 126 or hybrid cloud 128. A private cloud 124 may be owned by an organization and only the members of the organization with proper access can use the private cloud 126, rendering the data in the private cloud at least confidential. In contrast, data stored in a public cloud 126 may be open to anyone over the internet. The hybrid cloud 128 may be a combination of both private and public clouds 124, 126 and may allow to keep some of the data confidential while other data may be publicly available.

Referring back to Figs. 1 and 2, the battery or battery component identifiers provided by the identification element 12, 14, 32, 34 may be processed in an at least partially decentral computing environment or decentral network. Battery or battery component identifiers may be configured to access battery or battery component data, such as material data or material configuration data. Further decentral identifiers may be associated with recycling or production plants participating in the recycling or production of batteries. Recycling or production plant identifiers may be configured to access operation data, such as recycling or production plant data. Examples of operation data may be capacity data, process specific data or location data. By associating such decentral identifiers to authentication information and optionally authorization rules, data can be shared securely and reliably across players or systems of the production and/or recycling chain via the decentral network node(s) associated with such players, such as peer-to-peer communication.

Fig. 3d illustrates an example environment or decentral network for making data accessible according to standards set by the International Data Spaces Association (IDSA; e.g. IDS Reference Architecture Version 3.0 April 2019) or W3C (Decentral Identifiers (DIDs) v1.0, Core architecture, data model, and representations according to W3C Proposed Recommendation 03 August 2021). Such implementations aid to make data associated with decentral identifiers from material providers accessible to data consumers.

In the example, a data providing service 304 including a data retrieval system 308 and a connector 310 is sharing material data 316 with a data consuming service 306 including a data retrieval system 312 and a connector 314 via a decentral network protocol. The data providing service 304 and the data consuming service 306 are associated with network nodes or computing nodes of the network. The data providing service 304 and the data consuming service 306 are associated with local data bases 320a, 320b, which are controlled by the respective participant nodes.

Data relating to the battery identified or part(s) thereof may be provided or made accessible in association with material, component and/or battery 302 depending on the identifier for such data. The material, component and/or battery 302 may be related to the digital identifier. The digital identifier may include one or more decentral identifier(s) such as described e.g. in the context of Figs. 1-3. The decentral identifier may be an identifier in the decentral network 300 allowing for data exchange via the decentral network 300 between participant node(s) via data providing/consuming services 304, 306. One participant node of Fig. 3d may be associated with the data providing service 304. Another participant node of Fig. 3d may be associated with the data consuming service 306. Data exchange may include discovery of the decentral identifier for participant node(s) of the decentral network 300, authentication of participant node(s) of the decentral network 300 and/or authorization of data transfer via a peer-to-peer communication between participant node(s) of the decentral network 300.

Upon reading the identifier element via reader element 308 as e.g. described in Figs. 1 or 2, the digital identifier(s) of the respective battery, component or material may be provided e.g. via a decentral network data base (not shown). A digital relation between the identifiers may be provided, wherein the digital relation may reflect the physical relation of the battery, its components and its materials. The identifier(s) may be related to digital representation(s) of the battery data or part(s) thereof relating to the battery, components or materials thereof.

The battery identifier may include or relate to a decentral identifier(s), that is uniquely associated with the battery identified. Similarly, the identifier(s) may relate to components or materials of the battery. The decentral identifier may include one or more Universally Unique

Identifier(s) (UUID) or a Digital Identifier(s) (DID). The decentral identifier may include any unique identifier(s) uniquely associated with a data owner, battery, component and/or material. The data owner may be the producer of the battery, component or material. Via the decentral identifier and its unique association with the data owner battery, component and/or material access to the battery data may or part(s) thereof may be controlled by the data owner.

The decentral identifier(s) may be connected to the digital representation of the battery data associated with the battery, component(s) contained in the battery or material(s) contained in the battery. The digital representation may include a representation for accessing the battery data or part(s) thereof, such as material data or material configuration data as may be provided by the material producer. The digital representation(s) of battery data or part(s) thereof may be stored in a decentral data base (not shown). The battery data or part(s) thereof, such as material data or material configuration data, may be stored in a local data base associated with the data owner, such as the producer of the material, component or battery.

The battery 10 may be associated with or be related to a digital representation(s) of the battery data or part(s) thereof associated with the battery, component(s) of the battery and/or material(s) contained in the battery or its components. The digital representation(s) may relate to the respective digital identifier of the battery 10, the component and/or material contained in the battery 10 or its component(s). The digital representation(s) may point or be linked or provide a link to battery data or part(s) thereof, such as component(s) of the battery and/or material(s) contained in the battery or its components. The digital representation(s) may comprise at least one interface to the data providing service 304 configured to make the respective battery data or part(s) thereof accessible or to transfer the respective battery data or part(s) thereof. The digital representation(s) may include at least one interface to the data consuming service configured to access the respective battery data or part(s) thereof or to receive the respective battery data or part(s) thereof. The digital representation may include an endpoint for data exchange or sharing (resource endpoint) or an endpoint for service interaction (service eEndpoint), that is uniquely identified via a communication protocol. The digital representation(s) pointing to data related to the battery or parts thereof may hence be uniquely associated with the decentral identifier(s).

Upon providing the identifier(s), the representation pointing to the respective data, e.g. material data or material configuration data, may be provided to the data consuming service 306 e.g. via a decentral registry. In the example of material configuration data, which shall not be considered limiting, the material configuration data may be stored in a data base 310 associated with the material producer or provider. The data consuming service 306 associated with the reader 308 may request access to such data from the data providing service 304 of the material producer or provider. Authentication and/or authorization information linked to the identifier(s) may be

shared to authenticate and/or authorize access from the data consuming service 306 to the data provided by the data providing service 304. The authentication and/or authorization information may be provided for authentication and/or authorization of the data providing service 304 and/or data consuming service 306.

In one embodiment the data related to the battery of part(s) thereof points or is linked or includes a link to material configuration data or parts thereof. In one embodiment the data related to the battery of part(s) thereof includes one or more digital representation(s) pointing, linking or providing the link to battery data or material data or part(s) thereof stored in a local data base e.g. of the material provider. In this context pointing, linking or link means any network representation or address that is suitable for accessing the data related to the battery of part(s) thereof that is stored in a local data base. The data related to the battery of part(s) thereof may include multiple digital representations pointing, linking or providing the links to distinct parts of the battery data. The data related to battery may include multiple digital representations pointing, linking or providing the links to different parts of the battery data. Such different parts may overlap in some data points. The representation may include an access point to the battery data, a link to access battery data, an endpoint to access battery data and/or a service endpoint to access battery data. This way the battery data can be maintained and controlled by a data owner. Access can be provided via the representation of an access point simplifying data verification, integrity checks or quality checks and access control, since not multiple distributed data points need to be checked and access controlled. The battery data may be stored in the data base 320 of or associated with the data owner. The battery data may be stored in a data base 320 accessible by the data owner. The digital representation pointing, linking or providing the link to battery data or part(s) thereof may be associated with or relate to any such data base associated with or accessible by the data owner. For enhanced security the digital representation pointing to battery data or part(s) thereof may indirectly relate to any such data base associated with or accessible by the data owner.

Similar to the access and transfer of data as described above for the example of material configuration data, other data may be shared securely in decentral networks between different nodes associated with different players in the network. Any data provided in the different methods, embodiments, systems described may be provided by nodes of the decentral network.

An at least partially decentral structure based on decentral identifiers allows for novel methods, apparatuses, systems, computer elements, computer executable instructions and their uses in the battery recycling process, which will be described in the following.

Fig. 4 illustrates a flow diagram of an example method for providing material identifier package usable for the recycling of batteries, in particular a method for operating the recycling process based on material identifier package(s) or a method for sorting products to be recycled, such as batteries, based on material configuration data associated with product identifier(s).

Material identifier package(s) may include digital identifiers associated with products to be recycled such as batteries. By bundling digital identifiers according to associated material configuration, the products to be recycled, in particular the batteries, may be bundled physically by material configuration, which is otherwise not easily accessible from the physical product, in particular the battery. This way physical products such as batteries can be virtually or digitally bundled such that the recycling process can be executed more efficiently. To do so collecting, sorting and/or transporting instructions may be derived based on the material identifier package(s) to also physically bundle the respective products, in particular batteries, according to their material configuration and simplify recycling processes.

Battery identifiers associated with batteries to be recycled may be provided. Such data may be provided as described in the context of Figs. 1 -3 via the identifier elements physically connected to the battery or the component of the battery to be recycled. The battery identifiers may hence by associated with the battery and/or battery component(s) to be recycled. The identifier element of the battery may be read as described in the context of Figs. 1 and 2. The material data may be retrieved by the node of the decentral network associated with the reading of the identifier element. The decentral identifier(s) may be retrieved. Based on the decentral identifier(s) the digital representation(s) of battery data or part(s) thereof may be retrieved. The representation(s) may include links or pointers to the data. The battery data may include material configuration data. The material configuration data may be provided by the node of the decentral network associated with the producer of the product, components of the product or the material used to produce the product, such as cathode active material used to produce the cathode element of the battery 10. The node of the decentral network associated with the reading of the identifier element may request access to the material configuration data as e.g. described in the context of Figs. 1-3.

Based on the battery identifiers material data such as material configuration data may be accessed as e.g. described in the context of Figs. 1-3. For example, the cathode active material is valuable for the recycling processes due to the precious metals contained in the cathode active material. To recover and recycle such material for the production of new batteries, the material configuration data of the battery relating to the material configuration of the cathode

active material may be accessed. For instance, the material data may be accessed through a data service requesting access to the material data associated with each battery identifier and controlled by a material data owner. The data service may include computer executable instructions operating in an at least partially decentral computing environment. Such computer executable instructions may be based on a Json Web Token (JWT) including authentication information, authorization information and/or a digital representation pointing to material configuration data or parts thereof. The digital representation may include an endpoint for data exchange or sharing (resource endpoint) or an endpoint for service interaction (service endpoint), that may be uniquely identified via a communication protocol. The digital representation(s) pointing to material configuration data or parts thereof may be uniquely associated with the battery identifier.

The material data may include material configuration data associated with at least one component of the battery 10. The material configuration data may signify the material configuration of one or more component(s) of the battery 10. The material configuration may include the material type, the material properties, and/or the chemical composition of at least one component of the battery 10. Material type may include plastic, metal containing materials, polymer containing materials, composite materials as e.g. used in batteries 10 or in intermediate products, raw materials or by-products when producing batteries 10, but are not limited thereto. Material properties may include physical material properties, e.g. thermodynamic, mechanic, electrodynamic, optic and acoustic material properties, and/or chemical material properties, e.g. standard electrode potential and electronegativity, but are not limited thereto. The chemical composition may relate to one or more constituents and their amounts. The term component of a battery 10 may include all components included in a battery 10, e.g. cathode element 26 or anode element 24. For example, material configuration data may provide the cell chemistry such as cathode active material Al, Li, Co, Ni in percentage, anode active material such as graphite, composition electrolyte such as conducting salts or solvent, separators or other materials contained in the battery cells.

The material configuration data may be associated with the cathode element 26 or the cathode active material. In such an embodiment the material configuration may specify the chemical composition of the cathode active material. Examples are material configurations based on Lithium Nickel Manganese (NCM-type) such as Lithium Nickel Cobalt Manganese Oxide ($LiNiCoMnO_2$), Lithium Iron Phosphate (LPF-type) such as Lithium Iron Phosphate ($LiFePO_4/C$), Lithium Nickel Manganese (LMNO-type) such as Lithium Nickel Manganese Spinel ($LiNi_{0.5}Mn_{1.5}O_4$), Lithium Nickel Cobalt Aluminium (NCA-type) such as Lithium Nickel

Cobalt Aluminium Oxide (LiNiCoAlO2), Lithium Manganese (LMO-type) such as Lithium Manganese Oxide (LiMn2O4), Lithium Cobalt (LCO-type) such as Lithium Cobalt Oxide (LiCoO2) or combinations thereof. The material configuration data may be associated with the anode element 24 or the anode active material. In such an embodiment the material configuration may signify the chemical composition of the anode active material. Examples are natural graphite, artificial graphite, other graphite types or combinations thereof. The material configuration data may be associated with the electrolyte 22, the separator 28, the cell 18 or module packaging, the housing 20, or the like. For example, material configuration data may provide the cell chemistry such as cathode active material Al, Li, Co, Ni in percentage, anode active material such as graphite, composition electrolyte such as conducting salts or solvent, separators or other materials contained in the battery cells.

As illustrated in Fig. 6 the battery identifiers may be associated with different battery components and corresponding material configuration. In the example of Fig. 6 cathode element, anode element, separator element and housing are illustrative components. The cathode element may relate to the material configuration of the electrode active material, in the case of ID1 LMO and in the case of ID2 NCM. The anode element may relate to the material configuration of the anode active material, in the case of ID1 natural graphite and in the case of ID2 artificial graphite and silicon. Similarly, the material configuration for the separator may be specified by membrane type and the material configuration for the housing is specified by plastics type. In other embodiments the components, such as cathode element, anode element, separator element and/or housing may be associated with component identifiers respectively. Through the product identifier(s) and/or the component identifier(s) the respective material configuration data may be retrieved. The identifiers may include decentral identifiers.

Based on the material configuration data associated with the battery identifiers, at least one material configuration that is processable or to be processed by at least one recycling plant may be determined to provide material identifier package. As for example illustrated in Fig. 7 for the battery IDs of Fig. 6, two packages may be gathered: Package ID1 for the cathode element of the battery with ID1 having LCO as cathode active material and Package ID2 for the cathode elements of the battery with ID2 and IDn having NCM as cathode active material. Based on the material configuration data, batteries 10 or battery components 30 may be identified with material configuration that may be recycled by the same recycling plant or together. This way batteries or battery components to be recycled may be virtually sorted or gathered by way of the battery identifiers associated with such material configuration. For such determination different

embodiments are possible. Here only a few examples are described as illustrative embodiments, which are not considered limiting.

In one example a matching logic may be used to determine material identifier packages related to material configurations processable or to be processed by at least one recycling plant. Such matching may be based on the material configuration of one or more component(s). For matching multiple algorithms reaching from search algorithms to data driven classification models may be employed.

For instance, the matching may be conducted by chemical composition of components. For matching classification instructions may be provided. Such classification instructions may be pre-defined or dynamically adjustable. E.g. material configurations A, B, C may be pre-defined by at least parts of the chemical composition of one component such as specifying electrolyte composition, anode active material composition, cathode active material composition. A matching scheme may in principle look as follows.

Matching based on one component

Classification by component composition

A: Cathode active material x, y, z;

B: Cathode active material a, b, c;

C: Cathode active material d, e, f;

Material configuration of component

Battery ID 1, Cathode active material x

Battery ID 2, Cathode active material y

Battery component material configuration matching

Battery ID 1, Cathode active material x → class A

Battery ID 2, Cathode active material y → class A

For multiple components the material configurations A, B, C may be pre-defined by specifying at least in part the composition of multiple components. E.g. the composition such as housing composition, electrolyte composition, anode composition and cathode composition or the

composition of any other component may be pre-defined. A matching scheme may in principle look as follows.

Matching based on more components

Classification by component composition

A: Electrolyte x, y, z; anode l, m, k; cathode e,d,f

B: Electrolyte g, h, i; anode j, n, o; cathode p, q, r

Material configuration of components

Battery ID 1, Electrolyte x, anode l, cathode f

Battery ID 2, Electrolyte y, anode l, cathode e

Battery material configuration matching

Battery ID 1, Electrolyte x, anode l, cathode f → class A

Battery ID 2, Electrolyte y, anode l, cathode e → class A

In another example matching may be conducted by chemical composition of classes. Such matching may be based on the material configuration of one or more component(s). For instance, a search may be conducted by chemical composition. For searching classification instructions may be provided. Such classification instructions may be pre-defined or dynamically adjustable. E.g. material configurations A, B, C may be pre-defined by at least in part the chemical composition of one component such as specifying electrolyte composition, anode composition, cathode composition. E.g. material configurations A, B, C may be pre-defined by at least partial component composition specifying housing composition, electrolyte composition, anode composition and cathode composition and the composition of any other component. A searching scheme may in principle look as follows.

Classification by component composition

A: Electrolyte x, y, z; anode l, m, k; cathode e,d,f

B: …

C ….

Material configuration of components

Battery ID 1, Electrolyte x, anode l, cathode f

Battery ID 2, Electrolyte y, anode I, cathode e

Search battery material configuration by class

Class A: Battery ID 1, Electrolyte x, anaode I, cathode f;

Class B: Battery ID 2, Electrolyte y, anaode I, cathode e.

Once the matching or searching is done, batteries or battery components that are processable or to be processed by the recycling plant may be identified through their identifier associated with the respective material configuration. Such packages of battery or battery component identifiers may be assigned to the recycling plant by providing recycling plant data associated with recycling plants capable of processing such material packages.

In another example an advanced logic may be used. Such advanced logic may be based on the material configuration data of one or more component(s) and recycling plant data. For instance, recycling plant data may include a recycling plant identifier and a specification of one or more material configuration(s) processable or to be processed by the recycling plant performing at least one recycling process for one or more material configuration(s). This way the classification based on material configuration data may be directly related to a specific recycling plant. Respective, classification instructions may be provided that include on the material configuration data of one or more component(s) and recycling plant data.

Based on the determination of the material identifier package the material identifier package and associated battery identifiers may be provided. Material identifier package may hence include a collection of battery identifiers that are associated with one or more material configuration(s) processable or to be processed together in the recycling plant. A package identifier may be generated to by uniquely associated with such package. The battery identifiers associated with at least one material configuration processable or to be processed together may be linked to the package identifier. The package identifier may hence be associated with the batteries or battery components that are processable or to be processed together by at least one recycling plant or process. Material identifier package including the package identifier and/or the package of battery identifiers may be provided. In addition, material identifier package may include the material configuration(s) related to the package identifier or the package of battery identifiers. Material identifier package may include plant identifier(s) per package identifier or package of battery identifiers signifying the recycling plant the batteries or battery components are to be processed.

Optionally the material identifier package may be used to generate and provide sorting and/or collection instructions as described in more detail in the context of Figs. 5 and 14. Such instructions may be generated based on the package of battery identifiers or the package identifier and/or battery location data associated with the battery identifiers. One example of collection instructions include a user interface showing the pick-up scheduled. Sorting instructions may include machine-readable instructions which may be provided to sorting machine(s). Sorting machine(s) may read the product identifier(s) and sort the products or components in accordance with the material identifier packages. Sorting machine(s) may in other embodiments be provided with classification instructions as described above. The sorting machine may read the product identifier(s), sort the products or components based on classification instructions and generate virtual material identifier packages.

Further optionally the material identifier package may be used to generate and provide transport and/or storing instructions as described in more detail in the context of Figs. 5 and 14. Such instructions may be generated based on the package of battery identifiers or the package identifier, the location data related to the battery identifiers and/or operation data related to the plant identifiers. Location data may be associated with the physical location of the battery or battery component to be recycled. Operation data may include data indicative of the location of the plant, the capacity of the plant and/or process specifics of the plant.

Fig. 5 illustrates another example embodiment of a flowchart for providing material identifier package usable for recycling of batteries, in particular for operating a recycling process based on material identifier package(s) or a method for sorting products to be recycled, such as batteries, based on material configuration data associated with product identifier(s).

One or more waste product identifiers, in particular battery identifiers, and associated material configuration data may be provided e.g. as described in the context of Figs. 1, 2, 3d and 4. Material configuration data may be associated with material configuration such as material type, material characteristics or chemical composition associated with one or more product component(s) of the waste product is made of, such as the battery. A passive or active product identification element 12, 14, 32, 34 may be associated with the physical waste product, such as the battery. The identification element may be configured to provide waste product identifier, in particular the battery identifier, and associated material data for the physical waste product, in particular the battery, it is associated with or associated to as described in the context of Figs. 1 to 4. Additionally or alternatively, the product identifier, in particular battery identifier, may be

provided via a product element and the material configuration data may be provided through measurement.

Material classification instructions may be provided that classify the identifiers of one or more component(s) of the waste product, in particular battery, with respect to material type/characteristic or chemical composition. For a battery for instance, this may include classification by material configuration for one or more component(s) of the battery to be recycled. In one option the classification of material configuration classes A, B, C may be related to multiple components such as:

A: electrolyte x, y, z; anode (passive and active material) l, m, k; cathode (passive and active material) e,d,f; housing g, h, I; battery management system m, n, o; separator p, q, r;

B: electrolyte x2, y2, z2; anode (passive and active material) l2, m2, k2; cathode (passive and active material) e2,d2,f2; casing g2, h2, I2; battery management system m2, n2, o2; separator p2, q2, r2;

C electrolyte x3, y3, z3; anode (passive and active material) l3, m3, k3; cathode (passive and active material) e3,d3,f3; casing g3, h3, I3; battery management system m3, n3, o3; separator p3, q3, r3;

In another option the classification of material configuration classes A, B, C may be related to selected component(s) subject to recycling:

A: cathode (passive and active material) abc

B: cathode (passive and active material) def

C: cathode (passive and active material) ghj

Batteries or components may be classified by material configuration data by way of classification instructions. Material identifier package including number of batteries or components per class may be determined and provided. Waste products, in particular batteries or their components, may be classified based on their identifier, associated material configuration data and the provided material classification instructions. Based on the classified

battery identifiers the amount of material may be determined e.g. by number of batteries or components and/or by the amount of material to be recycled e.g. by battery component.

Plant identifiers may be provided in conjunction with operation data such as capacity data, process data and/or location data. Operation data may be associated with the plant identifiers and include capacity data, process data and/or material data or material classification instructions. The classified amount, number and/or composition of batteries or components based on classified component or battery identifier(s) may be matched to plant identifiers based on capacity, process specifics and/or location of the recycling plant. One plant identifier may be selected and provided based on the classified number, amount and/or composition of the package with respective battery identifiers or package identifer. Battery identifiers of one or more material classification(s) may be assigned to the recycling plant. Assignment may be based on pant capacity, process specifics, material configuration and/or material classification. Operation data may be static data relating to general specifications of a plant or it may be dynamic relating to current specifications of the plant. The latter allows for real time perspective on capacities, process data and/or material data. Plants can be matched based on real-time information allowing for more efficient and targeted use of plant resources in the recycling process. The material packages may be physically gathered by sorting, collecting, storing and/or transporting instructions based on packages of battery identifiers or the package identifier and potentially the plant identifier as e.g. described in the context of Fig. 4.

Collecting, sorting, storing and/or transport instructions for collector system, sorting system, storing system and/or transporting system may be generated and provided. Sorting instructions may be determined based on the material identifier package with the package of battery identifiers or the package identifier. The sorting instructions may relate battery identifiers provided by a sensor reading the battery identifier element to material configuration(s) processable or to be processed together, such as processable or to be processed by at least one recycling plant. Such relation may include using classification instructions providing material configuration(s) processable together, such as processable by at least one plant. Such relation may include using classification instructions relating the material configuration(s) processable together to at least one plant identifier. The sorting instructions may relate battery identifiers provided by a sensor reading the battery identifier element to battery identifiers comprised in the material identifier package. The sorting instructions may be provided to a sorting system for sorting batteries to be recycled. The sorting system may be controlled and/or monitored based on such instructions. In some embodiments classification instructions may be provided to the sorting system configured to read product or component identifiers from products or

components and to classify such identifiers for sorting the products or components. Such sorting allows for a simple and efficient sorting, since the logic for sorting may be implemented in the at least partially decentral computing environment and the sorting system may be based on a reading element combined with sorting hardware, such as a robot.

As illustrated in Fig. 14, the battery identifiers or component identifiers may be provided to the sorting system. The sorting system may be configured to monitor and/or control sorting of batteries or components associated with one or more class(es) based on sorting and/or classification instructions. The sorting system may be configured to monitor and/or control sorting of products or components by material configuration based on sorting and/or classification instructions. This way the sorting of products or components may be done via reading of identifiers associated with products or components simplifying the sorting of such batteries or components by material configuration.

Alternatively or additionally, collecting instructions based on the material identifier package may be determined. The collecting instructions may relate battery identifiers provided by a sensor reading a battery identifier element to material configuration(s) processable or to be processed together, such as processable or to be processed by at least one recycling plant. Such relation may include using classification instructions providing material configuration(s) processable or to be processed together, such as processable or to be processed by at least one plant. Such relation may include using classification instructions relating the material configuration(s) processable or to be processed together to at least one plant identifier. Further collection point data signifying the collection point of the at least on component of the battery may be provided. The collection point data may be included in the material identifier package. This way batteries may be sorted by targeted collection and simultaneously sorting may be realized on collection simplifying the recycling process.

As illustrated in Fig. 14, the waste product identifiers, in particular the batteries identifiers, associated with one classification may be provided to a collector system. The collector system may be configured to monitor and/or control collection of waste products, in particular batteries, associated with one or more class based on such instructions. The collector system may be configured to monitor and/or control collection waste products, in particular batteries, by material configuration based on collection and/or classification instructions. This way the sorting of waste products may be done directly on collection making a further sorting process redundant.

The collector system may be configured to collect waste products, in particular batteries, and provide waste product or battery identifiers for classification by material class. The classified waste product identifiers may be provided to a sorting system. Such providing may be directly from the collector system to the sorting system or indirectly via computing environment to the sorting system. The collector system may be configured to collect waste products, in particular batteries, and configured to classify waste product or battery identifiers by material configuration, to store associated identifiers and to provide waste product or battery identifiers per material class to the sorting system. The waste product or battery identifiers associated with one classification may be provided to e.g. the sorting system. The sorting system may be configured to sort collected waste products associated with one or more classes. The sorting system may be configured to provide identifiers for classification by material configuration and to sort waste products based on the material configuration. The waste product or battery IDs associated with one material classification may be provided by a collector system or computing environment.

Additionally or alternatively, transport instructions may be generated. Collection point data signifying the collection point of the battery or the at least on component of the battery may be provided. The collection point data may be included in the material identifier package. Transport instructions based on the collection point data and plant location data or storage location data may be determined. Based on such data one or more transport route(s) may be determined. The collection point data may signify the starting point for transport and the plant location data may signify the destination point of the transport route. Such transport route may be provided to a transport system such as an autonomous vehicle.

Additionally or alternatively, storing instructions based on capacity data and the number of batteries or components with material configuration processable or to be processed together may be determined. The amount of material or number of components per class or sub class may be determined based on the material classification. The amount of material may be provided to a storage system for managing the storage of waste products and/or to a transport system for transporting the waste products or to computing environment. The storage instructions may be provided to a storage management system or as transport instructions to the transport system.

A recycling run for recycled material may be scheduled by providing package identifier(s) to the plant operation system with plant identifier. The sorting, collection, storing and/or transporting

instructions may be provided to the recycling plant operation system. A recycling run may be scheduled for the respective package or class of batteries by providing the package of battery identifiers or the package identifiers to the recycling plant operation system. The assigned identifiers may be provided to the recycling plant operation system indicated by the recycling plant identifier in conjunction with material identifier package for scheduling recycling run.

Fig. 8 illustrates an example embodiment of a flowchart for providing plant assignment data usable for processing recycled battery material, in particular for operating a recycling process.

Recycled material data as illustrated in the examples of Figs. 4 and 5 for material identifier package usable for recycling of batteries, in particular for operating a recycling process may be generated and provided. Such identifier data may be used to operate the recycling process of mechanically and/or chemically recycling of at least one component of the battery. Recycled material data may include battery identifiers associated with the at least one material configuration that is processable or to be processed by at least one recycling plant. Such identifiers may be associated with a package gathering battery identifiers or a package identifier. For instance, the electrode element may be separated from the battery by way of dismantling and disassembling and further processed according to the package gathering battery identifiers. This way recycled material like black mass may be virtually tracked during the recycling process and such tracking may be used to operate the plant processing respective material of the battery.

Recycled material identifier and corresponding recycled material data associated with the recycled battery material may be provided. The recycled material identifier may relate to one or more battery identifier(s) and corresponding material configuration data of the batteries recycled to provide the recycled battery material. The recycled material data may be provided by computer-executable instructions running in an at least partially decentral computing or decentral environment, wherein the computer-executable instructions access the recycled material data of the recycled battery material based on the recycled material identifier. The material configuration data may be provided by the computing node of the decentral computing environment associated with the producer producing or using the material, such as the material producer. The material configuration data may be provided as part of the recycling material data. The material configuration data may be provided by battery or component identifiers included in the recycling material data and by accessing material configuration data via the battery or component identifiers. The recycling material data may include the material

composition of the recycled material as determined based on or on generation of the material identifier package. For access to recycled material data, the recycled material data provider may include one or more recycling system(s) generating the material identifier packages. The recycled material data may be provided by a computing node of a decentral computing environment associated with one or more recycling system(s), preferably configured to generate the material identifier package and/or determine the material composition of the recycled material based on the material identifier package. The recycled material identifier may relate to the material package identifier and corresponding material composition data associated with the recycled battery material. The recycled battery material may comprise battery cell(s) or black mass material provided by recycling electrode elements of the batteries.

Operation data associated with at least one operation property of the plant may be provided. Operation data may be provided by computer-executable instructions running in an at least partially decentral computing environment, wherein the computer-executable instructions access the operation data of the plant based on the plant identifier. The operation data may be provided by a decentral computing node associated with one or more plant(s), such as the recycling plant(s), and/or one or more recycling system(s), such as the collector, sorter, transport, storing system. The operation data may be provided for access or be accessed by a decentral computing node associated with one or more recycling system(s) and/or classification instructions relating the one or more plant(s) to recycled material data and/or recycled material identifier(s). The operation data may be accessed on request by a decentral computing node associated with one or more recycling system(s) and/or classification instructions relating the one or more plant(s) to recycled material data and/or recycled material identifier(s). The operation data may include classification instructions relating the one or more plant(s) to recycled material data and/or recycled material identifier(s). Operation data may be provided to determine plant identifiers identifying a plant suitable to process the recycled battery material associated with the recycled battery identifier data, such as recycled material data and/or the recycled material identifier. Operation data may include the plant identifier, the plant capacity related to a capacity of the plant, process data relating to process properties of the plant and/or material classification data related to material processable or to be processed by the plant are provided. Operation data may be provided or accessed in the decentral computing environment. The operation data may relate to static production properties of the plant and/or dynamic production propertied of the plant. Operation plant data may be static data relating to general specifications of a plant or it may be dynamic relating to current specifications of the plant. The latter allows for real time perspective on capacities, process data and/or material data. Plants can be matched based on real-time information allowing for more efficient and targeted use of plant resources in the recycling or production process.

Assignment of the plant identifier data, such as plant identifier(s), to the recycled battery identifier data, such as recycled material data and/or the recycled material identifier, may be based on plant capacity data, may include or be based on plant capacity data, process data and/or material data. The plant may be any recycling plant including mechanical, thermal, chemical or combination thereof. The plant may be a metallurgical plant for recovery of transition metals from battery materials. The metallurgical plant may be a hydrometallurgical plant and/or a pyrometallurgical plant. The recycled battery material may be assigned to a one-stage, two-stage or multi-stage process comprising at least one hydrometallurgical plant and/or a pyrometallurgical plant. The recycled battery material may contain electrode active material. The recycled material may be black mass.

Plant identifier data, such as plant identifier(s), may be determined by classifying according to classification instructions providing material data processable or to be processed by the plant. The classification instructions may be provided or executed by at least one node of the decentral computing system. Classification instructions may run in an at least partially decentral computing environment, wherein the classification instructions gather recycled material identifiers relating the one or more plant(s) to recycled material data, such as the recycled material composition, and respective plant identifier(s). The classification instructions accessing the recycled material data based on the recycled material or product identifier may initiate classification followed by transfer of the classified result. The classification instructions may be triggered by one or more recycling system(s) at any stage of the recycling process following generation of material identifier package. The classification instructions may access the recycled material data via the recycled material identifier as provided by one or more recycling system(s) and/or product identifier as provided by a material producer. The classification instructions may transfer the classification result to one or more recycling system(s), such as sorting, collecting, transporting or storing systems, and/or one or more plant(s), such as recycling and/or production plant(s).

Such classification instructions may include material compositions processable or to be processed by the plant. For instance, if the battery material composition signifies Li as a constituent, the plant assigned may be a hydrometallurgical plant. Further for instance, if Li is not contained as a constituent pyrometallurgical or hydrometallurgical plant may be assigned. In addition or alternatively, the determination of plant identifier data may include capacity or process specifics. For instance, if electrolyte fluid is part of recycled battery material the operations specifics of the plant, such as separation of electrolyte, may need to be adapted or a plant with appropriate process specifics may need to be assigned. Further for instance, if a plant

capacity is already filled another plant may be assigned. For instance, the quantity or amount of recycled battery material may be determined via the recycled battery material identifiers and the material composition data. The material composition may include a relative quantity or amount of the constituents and/or an absolute quantity or amount of material. Determining the plant identifier data production data may relate to production processes of the plant. Plant identifiers may be determined based on operation in connection with material classification. Plant identifiers may be provided. Plant assignment data comprising plant identifiers and related recycled material identifier(s) may be provided. This way the incoming recycled material can be identified and processed by the plant.

At least one plant identifier associated with a plant for processing the recycled battery material associated with the at least one recycled battery identifier is determined. Determining the at least one plant identifier may include selecting the plant identifier associated with the plant for processing the recycled battery material associated with the recycled battery identifier data based on the operation data. Determining the at least one plant identifier may include classification by classification instructions providing material data associated with one or more material configuration(s) processable or to be processed by at least one plant. Determining the at least one plant identifier may include matching the at least one recycled material identifier and the at least one plant identifier based on an amount of recycled battery material and a capacity of the plant. Determining the at least one plant identifier may include matching of the at least one recycled material identifier and the at least one plant identifier based on process data associated with one or more recycling process(es) and/or material data associated with at least one material configuration processable or to be processed by the at least one plant.

Plant assignment data comprising the at least one recycled material identifier related to the at least one plant identifier may be provided. From the plant assignment data transport and/or storing instructions may be determined and provided. At least one execution task to at least one manufacturing execution system of a plant may be provided and transmitted.

Transport and/or storing instructions based on location data associated with recycled material associated with the recycled material identifier and with the plant identifier may be generated and provided as disclosed in the context of Figs. 5 and 14. At least one execution task to at least one manufacturing execution system of a plant may be provided. The plant may be controlled and/or monitored according to the execution task.

Fig. 9 illustrates an example embodiment of a flowchart for assigning plants to operate the recycling process.

Battery identifiers and corresponding material configuration may be provided. Classification instructions for classifying the batteries by chemical composition of e.g. the cathode active material may be accessed or provided. The battery identifiers may be match according to the chemical composition from one or more batteries e.g. the cathode active material of the batteries. A package identifier associated with the chemical composition of the package, such as the black mass package, may be generated e.g. as disclosed in the context of Figs. 1-7 and 14, 15.

To match appropriate recycling plants for operating the recycling process, operation data and plant identifiers are accessed or provided. The operation data may include plant identifiers associated with process and capacity data. Based on the operation data, package identifiers are matched to the plant identifier. For instance, from the package identifiers the number of batteries or a quantity or an amount of material to be recycled may be determined. Based on the quantity or amount or the number and the plant capacity, the battery package may be assigned to a plant. The respective plant identifier may be provided in conjunction with the package identifiers associated with the package of batteries or battery material.

The packages may be gathered by storing or transport instructions based on package identifier and the plant identifier. Additionally or alternatively, the recycling run of the plant for the respective package of batteries may be scheduled by providing the package identifier to the recycling plant operation system.

Fig. 10 illustrates an example embodiment of a flowchart for assigning plants to operate a recycling process.

The battery identifiers and associated material configuration data as well as plant identifiers and associated operation data may be provided. The operation data may include capacity, material processing and process data related to the plant indicated by the plant identifier.

The capacity data may be matched with the quantity or amount of recycled material or the number of batteries associated with the battery identifiers. Additional matching criteria may be the process data and/or material processing data of the plant in connection with the material configuration data associated with the battery identifiers or recycled material data associated with the recycled material identifiers.

If no suitable plant is identified, storing instructions may be generated and the associated battery identifiers or recycled material identifiers may be stored in a database for non-assigned recycled material packages.

If a plant with capacity to recycle is identified, battery identifiers or recycled material identifiers may be matched with material processing data or process data.

If a suitable plant is identified, the battery identifiers or recycled material identifiers are assigned to the plant identifier. The assigned plant may then receive the identifiers to schedule the recycling process.

If no suitable plant is identified, storing instructions may be generated and respective identifiers may be stored in a database for non-assigned packages.

Figs. 11 to 13 visualize example data structures that may be implemented in an at least partially decentral or decentral environment based on decentral identifiers. Such data structure may be implemented in a decentral or central storage environment based on relational databases, graph databases or the like.

Battery identifiers may be associated with different components of the battery. Such battery identifiers may be matched and assigned to a package identifier as described in the context of Fig. 7. Via such virtual classification based on the associated material composition the packages may be collected and/or sorted to match the respective recycling process.

The packages may be assigned to the recycling plant for recycling the packaged material composition of battery materials. The package identifiers may be virtually assigned to the recycling plant identifier in the first and/or second stage of the recycling process as e.g. described in the context of Figs. 15 and 16.

The produced recycled material package may be assigned via associated package identifiers to a further recycling plant producing the recyclate. The recyclate may be assigned via associated package identifiers to a plant identifier associated with a plant using the recyclate to produce a new battery.

Fig. 14 illustrates an example system for operating the recycling process in the recycling chain of a battery.

At the start of the recycling chain stands the end-of-life product 1400. In this case the end-of-life product 1400 is a lithium-ion battery. The lithium-ion battery may include an identifier element as described in the context of Figs. 1 , 2. Such battery or component identifiers may be used in a decentral computing environment or network as lined out in the context of Figs. 3a to 3d.

The identifier(s) of end-of-life batteries 1400 may be provided by reading the identifier element with a reader 1404 e.g. as described in the context of Fig. 1, 2, 4, 5. On reading the identifier of end-of-life batteries material configuration data and other data such as condition data collected during the lifetime of the battery may be accessed via the identifier. The material configuration data may be accessed via a decentral computing network. For example, the material configuration data may be provided by the decentral computing node associated with the producer or user of the material.

Based on the material configuration data associated with the end-of-life battery 1400, the battery identifiers may be classified into packages of identifiers that may be processed together in the recycling chain that follows. For instance, the ID package generator 1406 may be configured to perform the methods described in the context of Figs. 4-5 for providing battery recycling data. Such data may be used for providing sorting and/or collecting the batteries by way of sorting and/or collecting instructions e.g. as described in the context of Figs. 4, 5. For instance, the collector and/or sorter system 1402 may be configured to receive such instructions

and to sort and/or collect batteries based on such instructions. In other embodiments, the reader 14040 and the ID package generator 1406 may be part of the collector and/or sorter system 1402. The batteries may be sorted directly on reading based on the classification provided by the ID package generator 1406.

Based on condition data associated with the end-of-life battery, the batteries may be discharged and/or disassembled by way of discharge and/or disassemble instructions. Such instructions may include an analysis of condition data collected during the lifetime, an end-of-life measurement protocol for collecting condition data from the end-of-life battery, an analysis of condition data collected by way of the end-of-life measurement protocol or any combination thereof. Analysis of condition data collected during the lifetime may include data related to self-discharge, charge/discharge processes, or state variables (e.g. cell temperature). This way further processing instructions on use of the battery 1400 may be determined without measurement effort. End-of-life measurement protocols may include the measurement of capacity, power, physical or chemical properties or resistance. Analysis of such measurement data may lead to further processing instructions on use of the battery. Alternatively or additionally, such instructions may include discharge and/or disassembling instructions for robotic systems. For instance, the discharger and/or disassembler system 1404 may be configured to receive such instructions and to disassemble and/or discharge batteries 1400 based on such instructions.

The components of the end-of-life battery such as cell, cathode elements, anode element, electrolyte, separator or housing may be associated with the battery identifier and/or separate component identifiers. Based on the identifier packages as provided by the battery recycling data transport and/or storing instructions may be generated for the battery or if disassembled for battery component(s) e.g. as described in the context of Figs. 4, 5. For instance, the transport and/or storing system 1406 may be configured to receive such instructions and to transport and/or store the batteries or component(s) based on such instructions. The collector and/or sorter system 1402, discharge and/or dissembler system 1404 and the transport and/or storing system 1406 may be recycling systems connected via a decentral computing network. The systems may be associated with computing nodes of the decentral computing system. Each node may be configured to access or provide data in the decentral computing system.

Based on battery recycling data associated with battery identifiers and operation data associated with plant identifiers, the batteries or component(s) of the battery may be assigned

to a plant identifier by providing plant assignment data as described in the context of Figs. 6 to 8. The plant associated with the plant identifier may by a mechanical or chemical recycling plant. The plant assignment data may include more than one plant identifier if the recycling chain includes more than one recycling plant. For instance, as shown in Figure 15 for cathode elements, the recycling chain may include mechanical followed by pyrometallurgical followed by hydrometallurgical processing of battery materials to be provided as recycled battery martials to a production process. In another option the recycling chain may include mechanical followed by hydrometallurgical processing of battery materials to be provided as recycled battery martials to a production process. Recycling processes provide transition metals separately or already in the desired stoichiometries for making a new material. For instance, the plant assignor 1408 may be configured to provide plant assignment data and to provide such plant assignment data to chemical/mechanical recycling system 1410 of respective plants associated with the plant identifier(s). Based on the plant assignment data and location data transport and/or storing instructions may be generated by transport and/or storing system as described herein e.g. Figs. 4, 5, 6, 7, 8. For instance, the plant assignor 1406 may be configured to provide plant assignment data and to provide such plant assignment data to production system 1416 of respective production plants associated with the plant identifier(s). The plant assignor, the transport and/or storing system 1406 and the chemical recycling system may be part of a decentral computing environment. Each system may be associated with a computing node of the decentral computing system to access and/or provide data in the decentral computing network.

Based on the tracked recycling material packages and recyclate data production data may be provided by recyclate quota generator 1418. Any computation may be executed via a computing environment. The computing environment may be based on a decentral computing architecture as described in the context of Figs. 3a to c. The collector system 1402 may include collection mechanisms to collect batteries or components of batteries 1400 to be recycled. The sorting system 1402 may include mechanisms to sort batteries or components of batteries 1400 to be recycled. The recycling system 1410 may include a recycling plant for recycling batteries or components of batteries 1400 to be recycled. The output of the recycling system 14010 may be a recycled material suitable for use in a production plant. Recycling plants may include chemical, mechanical, thermal and/or magnetic recycling plants. The production system 1416 may include a production plant for producing batteries and/or components of batteries based at least in part on recycled material as provided by the recycling plant. The input material of the production plant may include virgin material and recycled material. The collector system, 1404, the discharger system 1404, the transport and/or storing system 1406, the computing environment, the sorting system 1402, the production system 1416 and/or the recycling system

1410 may be communicatively coupled to each other. The communication may be a peer-to-peer communication provided by the decentral computing environment as described in the context of Fig. 3d. The ID package generator 1406, the plant assignor 1408, the recyclate content generator 1418 may be decentral service application or may be part of one or more computing nodes associated with the recycling system or the plants.

The computing environment, the collector system or the sorting system 1402 may be configured to generate collection and/or sorting instructions based on the material identifier package as e.g. described in the context of Figs. 4, 5. The computing environment, the collector system, the sorting system 1402, the production plant system 1416 or the recycling plant system may be configured to generate transport and/or storing instructions based on the material identifier package as e.g. described in the context of Figs. 4, 5.

The collector system and/or the sorting system 1402 may be configured to provide battery identifiers to the computing environment. The battery identifiers may be provided via the identification element as described in Figs. 1 – 2. For instance the collector system and/or the sorting system 1402 may be configured to read the QR code of the battery or the component of the battery. The collector system and/or the sorting system 1402 may be configured to provide location data to the computing environment. Location data may be provided by a user terminal such as a sensor reading the identification element or by an identifier of the system registering with the service. For instance, a user accessing the service may provide the location data.

The computing environment with decentral computing nodes, collector system and/or the sorting system 1402 may be configured to access material data based on the provided battery identifier. The computing environment may include the ID generator configured to determine material identifier package including package of battery identifiers as described in the context of Figs. 4, 5. The computing environment, collector system and/or the sorting system 1402 may be configured to provide material identifier package for operating the recycling process. The computing environment, collector system and/or the sorting system 1402 may be configured to provide collection instructions and/or sorting instructions.

For instance, the computing environment or a node of the computing environment may be configured to determine, based on the locations of the batteries associated with the material identifier package, collection point data signifying the collection location for the batteries or

battery component to be recycled. The collection instructions may include the collection locations. Collection instructions may be provided to the collector system. The collection instructions may include the collection locations for each package identifier or package of battery identifiers included in the material identifier package. This way batteries or components of batteries may be collected in such a way that they are processable or to be processed together and further sorting is not needed. The collector system 1402 may be configured to collect batteries or components of batteries to be recycled, preferably by material configuration. This way the sorting of batteries or components of batteries to be recycled may be done directly on collection making a further sorting process redundant. The collector system 1402 may be configured to collect batteries or components of batteries to be recycled, to provide battery IDs for generating material identifier package according to classification instructions or to provide material identifier package e.g. to a sorting system, to classify battery IDs according to classification instructions, to store associated recycling data or to provide associated recycling data e.g. per material configuration to a sorting system.

Further for instance, the computing environment or nodes of the computing environment may be configured to generate sorting instructions based on the package identifiers or the collections of battery identifiers. The sorting instructions may include the battery identifiers per package. The sorting instructions may be provided to a sorting system. The sorting system may be configured to provide the battery identifier per battery or battery component to be recycled and to sort such batteries or battery components based on the provided sorting instructions. This way batteries or components of batteries may be sorted by reading the identification element in such a way that they are processable or to be processed together.

The computing environment, the collector system 1402, the sorting system 1402, the production plant system 1416 or the recycling plant system 1410 may be configured to generate transport and/or storing instructions based on the material identifier package. Based on location data of the batteries or the components to be recycled and based on the target location of the batteries or the components to be recycled transport instructions may be determined. The target location may relate to the recycling plant to process the material configuration. Based on the capacity of the recycling plant and/or based on the number of batteries or components per package identifier or per package of battery identifiers, storing instructions may be determined. If a plant capacity is higher than the number of batteries or components per package collected for the material configuration, storing instructions may be generated. Such storage instructions may include a storage location for storing batteries or their components until the number reaches the capacity of the plant.

As described above different variations exist to implement the methods, apparatus and systems described herein. Different systems may implement different method steps or service component. The described embodiments are only examples and should not be considered limiting.

Fig. 15 illustrates example recycling chains for cathode active materials.

Batteries comprise different parts of material as described in Fig. 1. The recycling chain may comprise different steps and may have different designs. First the end-of-life battery may be discharged followed by dismantling. The batteries may be discharged and disassembled to separate components such as the cells. The components of the battery may be fed into subsequent recycling streams. For instance, mechanical processing may follow. This may include mechanical crushing (shredding) of battery cells and separation of materials. Electrolyte residues may be removed from active materials by drying or pyrolysis before the following process steps. Mechanical separation of „Black Mass" (e.g. Co, Ni, Mn, C), current-conducting foils and separator parts may be implemented by a combination of crushing, drying, sorting, and classification processes. The materials may be sorted by their physical properties such as particle size, form, density, and electric and magnetic properties. For instance, the foil and the active material including transition metals may be separated. Such recycled material may be called black mass.

The separated components may be fed into subsequent recycling streams. For instance, the cells of the battery may be recycled to recover transition metals comprised in the electrode elements. In particular, lithium-ion batteries comprise electrode active material comprising lithium. The recycling process may follow different process layouts depending on the material configuration used in the cells of the lithium-ion battery. The recycled material from mechanical recycling may be further processed by pyrometallurgy and/or hydrometallurgy. For instance depending on the composition of the recycled battery material pyrometallurgy, hydrometallurgy or a combination of both may be used. One process design may be based upon pyrometallurgical followed by hydrometallurgical processing of battery scrap materials. Another process design may be based on the direct hydrometallurgical processing of battery materials. Such processes will transition metals separately or already in the desired stoichiometries for making a new cathode active material.

Based on the virtual packaging of batteries by the material composition via the batter identifiers the material composition of the recycled material may be tracked. Furthermore, the composition of the recycled battery material may be determined by classifying the battery identifiers based on the associated material composition. This way the composition of the recycled battery material may be tailored to subsequent recycling process steps. Furthermore, such tracking of the recycled material may be performed up to the recyclate and the tracking may be used for tracking e.g. the availability of recyclate or recyclate compositions. The decentral computing environment giving access to specific material data via the identifiers allows for reliable and efficient operation across the recycling process from end-of-life product to recyclate that may be re-used in the production of new material.

Fig. 16 illustrates an example flowchart of a method for providing a recyclate feed content for producing at least one component of the battery.

Recycling data associated with the use of recycled precursor material in the production of the at least one component of the battery may be provided. The recycling data may indicate recyclate feed content for the at least one component of the battery. The recyclate feed content may specify the total recyclate feed content for the component or the recyclate feed content per precursor. The recycling data may include a recyclate amount or quota for one or more precursor product(s). For instance, for the electrode active material of lithium-ion batteries certain recycling amount or quota may be provided for certain precursors, such as metals like cobalt, lithium, copper or nickel. Additionally or alternatively, a total recyclate feed content for the at least one component of the battery may be provided. For instance, for lithium-ion batteries a total amount or rate for recyclates independent of the precursor(s) may be provided. Such total amount or rate may relate to individual components, to a combination of components or to all components of the battery. For instance, for lithium-ion batteries the total amount or rate may relate to the electrode element including the electrode active material, to the anode element including the anode active material, to the cell with its components or to the battery with its components. The recycling data may for example specify 20% of copper to be recycled copper, 10% of lithium to be recycled lithium, and 12% of nickel to be recycled nickel. The recycling data may for example specify 15% or 20% of transition metals to be recycled transition metals. The recycling data may for example specify 30% of materials used for producing the component of the battery to be recycled material. Fig. 20 depicts one embodiment of a user

interface for entering recycling quotas. In other embodiments such data may be provided through an application programming interface or any other service providing such data.

Operation data associated with at least one operation property of at least one production plant may be accessed and provided. Such operation data may relate to the availability of one or more recycled precursor(s) for producing the at least one component of the battery. For instance, the availability may be derived from storage levels for different recycled precursors, from recyclate package identifiers associated with amounts of recycled precursors available from recycling processes, or from recycled material identifiers including batter identifiers associated with amounts to be recycled and available from recycling processes. Such availability data may further be associated with plants. For instance, certain material may be available for production plants in the vicinity of the plant. Other examples of operation data may include capacity data indicating the current capacity of the production plants, process data indicating process specifics of the production plants, performance data indicating performance specifics of the production plants or emission data associated with the production plants.

Based on the recycling data and the operation data, a recyclate feed content of one or more recycled precursor(s) may be determined. The recyclate feed content for one or more precursor(s) may be determined depending on the recyclate amount of one or more precursor product(s), the recyclate quota for one or more precursor product(s) and/or the total recyclate feed content for the at least one component of the battery to be produced. For instance, if recyclate amount or quota are provided, the minimum recyclate feed content may correspond to the recyclate amount or quota.

Further operation data may be considered for determining the recyclate feed content for one or more recycled precursor(s). The operation data may include availability data derived from battery identifiers. Said availability data may signify the amount of recycled material available from the recycling process. Such amount may be derived from battery identifiers and the material tracking as disclosed herein. Advantageously the recyclate package identifiers associated with amounts of recycled precursors available from recycling processes, or the recycled material identifiers including battery identifiers associated with amounts to be recycled and available from recycling processes can be easily accessed in a decentral computing environment, enabling the connection between recyclate feed content for production and the recycled material from recycling processes. This way a reliable and environmentally friendly management of material resources in combination with physical recycling and production can

be achieved, which is particularly advantageous in the distributed system of material flows, recycling plants and production plants.

If for instance the availability data of the precursors is provided, the recyclate feed content for those precursors with high availability may be increased compared to the recyclate amount or quota. This way the recyclate feed content and the production may be tailored to adapt the recyclate feed content. Further for instance, if the total amount or quota is provided, the recyclate feed content may be distributed across different precursors. If the availability data of the precursors is provided, the recyclate feed content for those precursors with high availability may be increased compared to the recyclate feed content for precursors with lower availability. This way the recyclate feed content and the production may be tailored to adapt the recyclate feed content.

In particular, determining the recyclate feed content may concern the process for making electrode active materials for lithium-ion batteries. In such process first a precursor may be formed by co-precipitating transition metals as carbonates, oxides or preferably as hydroxides that may or may not be basic. The process for making particulate (oxy)hydroxide of transition metal is for instance described in WO2021244963A1, which is herewith incorporated by reference. Said particulate (oxy)hydroxide may serve as a precursor for electrode active materials, and it may therefore also be referred to as precursor. Formation of transition metal-based precursors may include recycled transition metals as provided according to the determined recyclate feed content for transition metal precursors. The transition metal-based precursor may then be mixed with a precursor source of lithium such as, but not limited to LiOH, Li2O or Li2CO3 and calcined (fired) at high temperatures. The process for making an electrode is for instance described in WO2020/069882A1, which is herewith incorporated by reference Lithium salt(s) can be employed as hydrate(s) or in dehydrated form. The calcination - or firing - generally also referred to as thermal treatment or heat treatment of the precursor – may be carried out at temperatures in the range of from 600 to 1000 °C. During the thermal treatment a solid-state reaction takes place, and the electrode active material is formed. Lithium containing precursors may include recycled lithium or precursors formed from recycled lithium. Recycled lithium or precursors formed from recycled lithium may be provided according to the recyclate feed content for such precursors.

The determined recyclate feed content of one or more recycled precursor(s) for production of at least one component of a battery may be provided to generate instructions for operating the

production plant. For instance, based on the composition of the component and the recyclate feed content per precursor, instructions for monitoring and/or controlling the product feed may be generated and provided to the operation system of the production plant. Apart from the feed further operation instructions for monitoring and/or controlling operation of the production plant may be generated and provided. Such further instructions may include different operation parameters depending on the feed compositions or the recyclate feed content. The operating plant may be operated based on the provided instructions for monitoring and/or controlling operation of the production plant.

Figure 17 illustrates another example of the method for providing a recyclate feed content for producing at least one component of the battery based on availability data and optionally including the selection of a production plant.

Recyclate feed content may be determined e.g. according to the example embodiment of Fig. 16. Recycling quota per precursor for battery component to be produced may be provided e.g. via a user interface as depicted in Fig. 20. This may for instance include recycling quota for metal constituents contained in the electrode active material. Such recycling quota may be validated by accessing a regulatory database. It may be checked if the recycling quota is regulated. If the recycling quota is regulated, it may be checked if the provided recycling quota conforms the regulated recycling quota. If the recycling quota does not conform regulatory requirements, it may be adapted accordingly. For instance the recycling quota as regulated may be used.

In this example precursor identifier and availability data may be provided to determine the recyclate feed content. The precursor identifier may be associated with at least one precursor and the amount of recycled precursor available. The precursor identifier may be associated with an amount of recycled precursor available. The precursor identifier may relate to recycling material identifier or it may be derived from battery identifiers and the tracking in the recycling process. Determination of the recyclate feed content may be made by matching the provided recycling quota per precursor with availability data per precursor. Such matching may be performed per precursor as described in the context of Fig. 16 and may consider the adapted recycling quota per precursor based on regulatory check as described above.

In addition, capacity data related to the production capacity for one or more production plants, process data relating to process specifics of one or more production plants, performance data relating to performance characteristics of one or more production plants and/or emission data relating to emission(s) for producing the at least one component of the battery may be provided. Emission data may include emissions from precursor materials and the at least one production plant for producing the component of the battery. The emission data may include at least one emission target for use of precursor(s) in the production of the at least one component. The emission data may include a total emission target for producing the at least one component. Emission targets may be provided via a user interface as for instance depicted in Fig. 22. Here total emissions, production emissions and other emissions such as transport emissions may be provided by a user. In other embodiments such data may be provided through an application programming interface or any other service providing such data.

Based on the capacity data and/or the emission data, a plant for processing the recyclate and for producing the at least one component using the recyclate feed content may be selected. Selecting the production plant for producing the component may depend on the determined recyclate feed content in combination with process data and/or capacity data to determine, if the plant is suitable for processing the recyclate. Selecting the production plant for producing the component may also depend on emission data and/or performance data. The production plant meeting at least one emission target for use of precursor(s) and/or the total emission target for producing the at least one component may be selected. The selection of the production plant may be based on a multi-dimensional metric defining a distance and/or a threshold measure. The distance and/or threshold measure may be determined from the determined recyclate feed content in relation to process data and/or capacity data, the recyclate feed content in relation to the at least one emission target for use of precursor(s) and/or the total emission target for producing the at least one component.

Further based on the process data, the composition of the recyclate, e.g. as tracked via the identifiers across the recycling chain, may be used to match the process specifics of the plant with the process specifics required for the recyclate composition. For instance, in case of electrode active material the recyclate may be available in the desired stoichiometry required for producing the electrode active material or transition metal recyclate may be available separately. In such case the recyclate with the desired stoichiometry may be selected in combination with a suitable plant to produce the electrode active material from such recyclate. The plant may be an electrode active material production plant or cathode active material (CAM) plant for processing transition metal carbonates, oxides or hydroxides as precursors. If

only transition metal recyclate is available, another suitable plant to produce the electrode active material or cathode active material from such recyclate may be selected. The plant may be a precursor electrode active material production plant or a precursor cathode active material (PCAM) plant for processing transition metals as precursors.

Operation instructions for controlling and/or monitoring the production system such as a precursor feed of at least one virgin precursor and/or at least one recycled precursor may be generated and provided. Further operation instructions for controlling and/or monitoring the operation of the selected plant may be determined e.g. based on the determined recyclate feed content, emission target(s), performance data and the selected production plant. The operation instructions for controlling and/or monitoring the operation of the selected plant may be provided to a production system. The production plant may be operated based on such operation instructions.

Figure 18 illustrates another example of the method for providing a recyclate feed content for producing at least one component of the battery including chemical performance check.

Recyclate feed content may be determined e.g. as described in the context of Figs. 16 and 17. For such determination recycling content for the component or per precursor may be provided. In addition, target performance parameter(s) for the component may be provided. The recycling data may include recycling content and target performance parameter(s) associated with the expected performance of the produced component. The target performance parameter(s) may relate to the at least one component or the at least one component in relation to other components. For instance, the performance of an electrode active or anode active material may be provided. In case of a lithium-ion batteries such performance parameters may relate to energy density, charge density, degradation behavior, capacity or the like. Target performance parameter(s) may be provided via a user interface as for instance depicted in Fig. 22. Here charge density, capacity and degradation may be provided by a user. In other embodiments such data may be provided through an application programming interface or any other service providing such data.

In addition, availability data per recycled precursor may be accessed and provided. Recyclate feed content may be determined e.g. as described in the context of Figs. 16 and 17. Determining the recyclate feed content may include the determination of the chemical

performance associated with the component to be produced by using the recyclate feed content. From the determined recyclate feed content of the one or more precursor(s) the chemical composition of the at least one component may be determined considering virgin and recyclate feed content. For such composition the chemical performance of the at least one component to be produced may be determined. For instance, the energy density or capacity resulting from the chemical composition of the electrode or anode active material may be determined based on a first principles model, a data driven model or a combination of both.

Hence, based on the determined recyclate feed content the chemical performance parameter(s) associated with the component to be produced depending on the determined recyclate feed content may be determined. Such determined chemical performance parameter(s) may be compared to the provided target performance parameter(s) to determine, if the component produced with the feed composition fulfills the required chemical performance.

If the chemical performance is fulfilled for the determined recyclate feed content, operation instructions for controlling and/or monitoring the production system such as a precursor feed of at least one virgin precursor and/or at least one recycled precursor may be generated and provided. Further operation instructions for controlling and/or monitoring the operation of the selected plant may be determined e.g. based on the determined recyclate feed content, emission target(s), performance data and the selected production plant. The operation instructions for controlling and/or monitoring the operation of the selected plant may be provided to a production system. The production plant may be operated based on such operation instructions.

Figure 19 illustrates another example of the method for providing a recyclate feed content for producing at least one component of the battery including emission target check and optionally plant selection.

Recyclate feed content may be determined and provided as e.g. described in the context of Figs. 16, 17 and 18. Optionally a plant for processing recyclate may be selected based on emission target(s) and capacity data as e.g. described in the context of Figs. 16 and 17. From such selection the emissions related to the precursor material and the selected production plant may be determined to check emission targets are met.

If emission targets are not met, the recyclate feed content may be re-determined based on the total emission target or the recyclate feed content may be determined based on the at least one emission target for use of precursor(s). Optionally a different plant may be selected.

If emission targets are met, operation instructions for controlling a precursor feed of at least one virgin precursor and/or at least one recycled precursor based on the determined recyclate feed content and/or the selected production plant may be generated. The operation instructions for controlling and/or monitoring e.g. a precursor feed of at least one virgin precursor and/or at least one recycled precursor may be provided. Further operation instructions for controlling and/or monitoring operation of the selected plant may be determined based on the determined recyclate feed content and the selected production plant. The operation instructions for controlling and/or monitoring operation of the selected plant may be provided e.g. to the production system. The production plant may be controlled and/or monitored according to the operation instructions.

The present disclosure has been described in conjunction with a preferred embodiment as examples as well. However, other variations can be understood and effected by those persons skilled in the art and practicing the claimed invention, from the studies of the drawings, this disclosure and the claims. Notably, in particular, the any steps presented can be performed in any order, i.e. the present invention is not limited to a specific order of these steps. Moreover, it is also not required that the different steps are performed at a certain place or at one node of a distributed system, i.e. each of the steps may be performed at a different nodes using different equipment/data processing units.

As used herein „determining“ also includes „initiating or causing to determine“, “generating”, “querying“, “accessing”, “correlating”, “matching”, “selecting” also includes „initiating or causing to generate, access, query, correlating, select and/or match“ and “providing” also includes “initiating or causing to determine, generate, access, query, correlating, select and/or match, send and/or receive”. “Initiating or causing to perform an action” includes any processing signal that triggers a computing node to perform the respective action.

In the claims as well as in the description the word “comprising” or “including” does not exclude other elements or steps and the indefinite article “a” or “an” does not exclude a plurality. A single element or other unit may fulfill the functions of several entities or items recited in the

claims. The mere fact that certain measures are recited in the mutual different dependent claims does not indicate that a combination of these measures cannot be used in an advantageous implementation.

Claims

1. A computer-implemented method for operating a battery recycling process for recycling of materials contained in batteries associated with at least one battery identifier, the method comprising the steps of:
   - providing at least one battery identifier and corresponding material configuration data associated with at least one component of the battery to be recycled;
   - determining at least one material identifier package by relating the at least one material configuration provided by the material configuration data to at least one material configuration processable by at least one plant;
   - providing the at least one material identifier package usable for recycling batteries including the at least one battery identifier
   - operating based on the at least one material identifier package the product recycling process for recycling of materials contained in products associated with the at least one product identifier.

2. The method according to claim 1, wherein the material configuration data relates to the chemical composition of the electrode active material.

3. The method according to any one of the preceding claims, wherein the material configuration data associated with the material used to produce the battery or the component of the battery is provided by a decentral computing node associated with a producer producing or using the material.

4. The method according to any one of the preceding claims, wherein the at least one material identifier package includes a gathering of battery identifiers associated with batteries or components to be recycled and/or with the at least one material configuration processable by at least one recycling plant.

5. The method according to any one of the preceding claims, wherein the at least one material identifier package includes material composition data associated with the recycled battery material as produced from at least one recycled component of the battery, wherein the material composition data is determined from the battery identifiers and their corresponding material configuration data.

6. The method according to any one of the preceding claims, wherein determining the at least one material identifier package includes classification according to classification instructions providing the material configuration(s) processable by at least one plant.

7. The method according to any one of the preceding claims, wherein determining the at least one material identifier package includes providing classification instructions running in an at least partially decentral computing environment, wherein the classification instructions gather battery identifiers according to material configuration(s) processable by at least one recycling plant.

8. The method according to any one of the preceding claims, wherein the battery identifier is provided from a sensor reading a battery identifier element, wherein the battery identifier element is physically connected to the at least one component of the battery to be recycled.

9. The method according to any one of the preceding claims, wherein the material configuration data associated with the material used to produce the battery or the at least one component of the battery is accessed by a decentral computing node associated with one or more recycling system(s) or associated with classification instructions.

10. The method according to any one of the preceding claims, wherein the recycling process is operated by providing the material identifier package for controlling and/or monitoring recycling system(s).

11. An apparatus for operating a battery recycling process for recycling of materials contained in batteries associated with at least one battery identifier, the apparatus comprising: one or more computing nodes; and one or more computer-readable media having thereon computer-executable instructions that are structured such that, when executed by the one or more computing nodes, cause the apparatus to perform the following steps:
    - providing at least one battery identifier and corresponding material configuration data associated with at least one component of the battery to be recycled;
    - determining at least one material identifier package by relating the at least one material configuration provided by the material configuration data to at least one material configuration processable by at least one plant;
    - providing the at least one material identifier package usable for recycling batteries including the at least one battery identifier

- operating based on the at least one material identifier package the product recycling process for recycling of materials contained in products associated with the at least one product identifier.

12. Use of a battery comprising at least one battery identifier element in a method according to any one of claims 1 to 10 or with an apparatus according to claim 11.

13. Use of the material identifier package generated according to the methods of any of claims 1 to 10 to sort, collect, transport, store and/or recycle at least one component of a battery to be recycled.

14. A method for sorting, collecting, transporting, storing and/or recycling at least one component of a battery to be recycled, the method comprising the steps: providing at least one material identifier package according to the methods of any of claims 1 to 10; operating the recycling process based on the at least one material identifier package by generating sorting, collecting, transporting, storing and/or recycling instructions based on the provided material identifier package and providing sorting, collecting, transport, storing and/or recycling instructions for monitoring and/or controlling recycling system(s).

15. Computer element with instructions, which, when executed by at least one computing nodes of a computing environment, are configured to carry out the steps of the method according to any one of the claims 1 to 10, 14 or to carry out steps as provided by the apparatus of claim 11.

Fig. 1

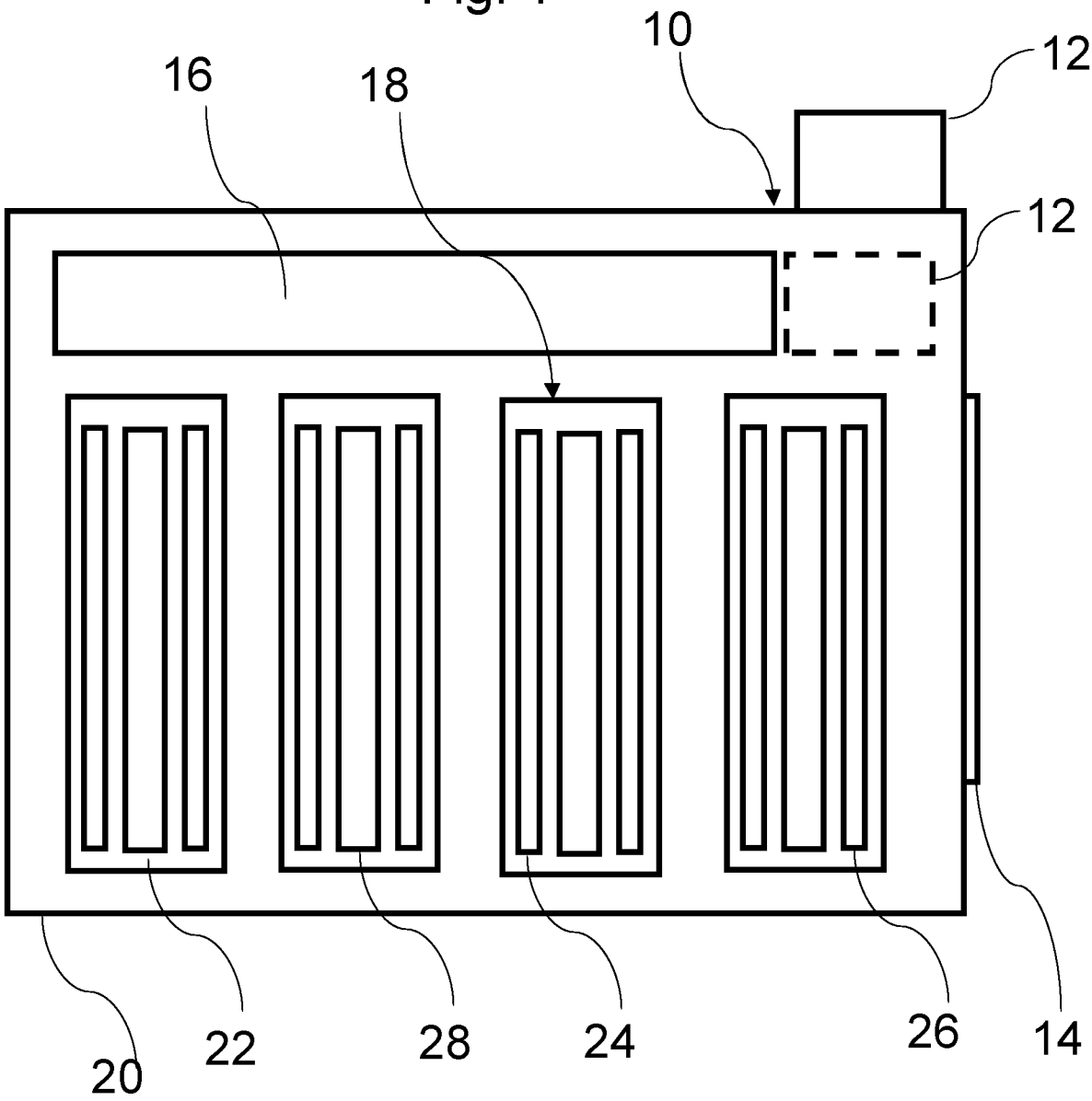


Fig. 2

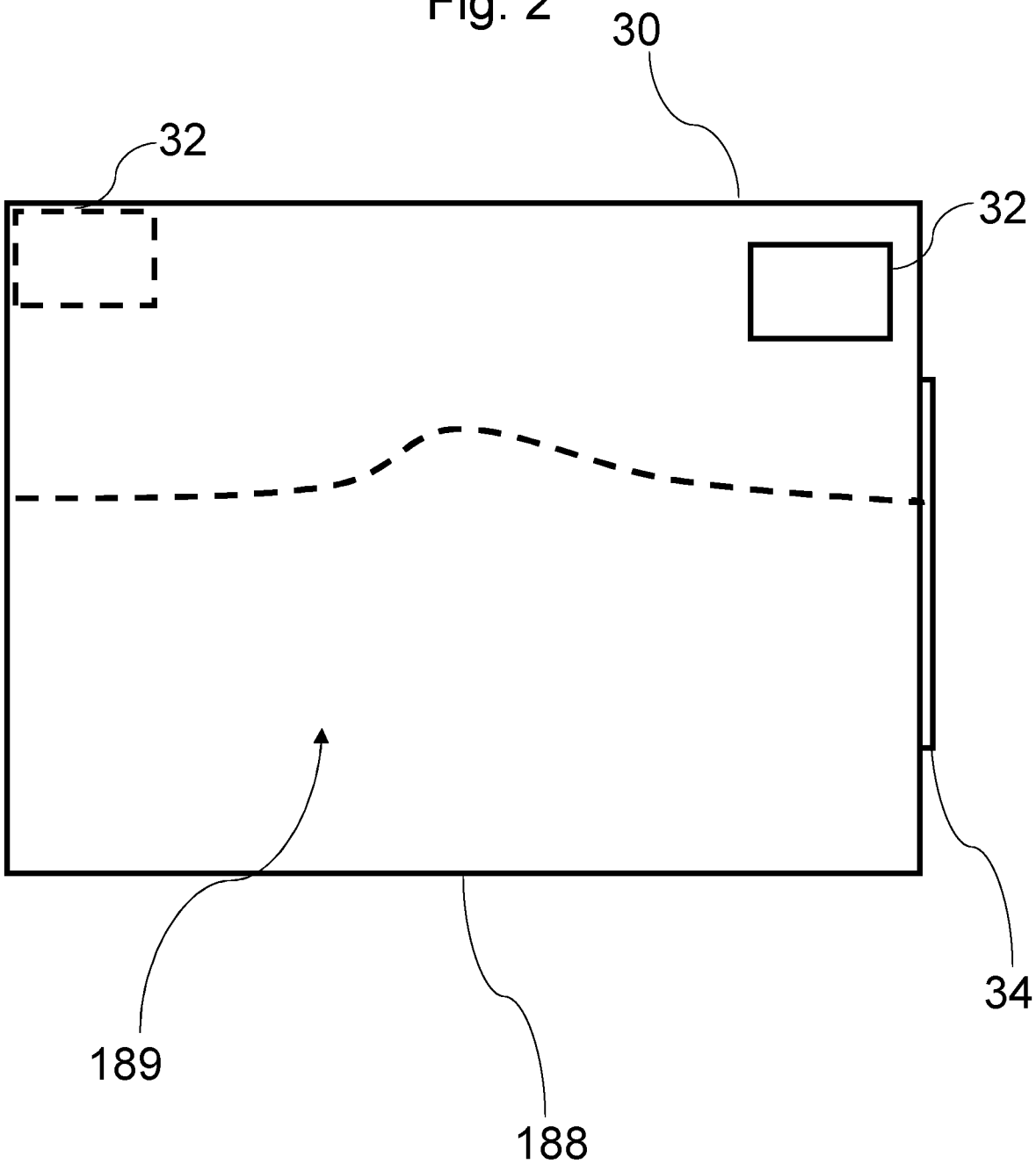


Fig. 3a

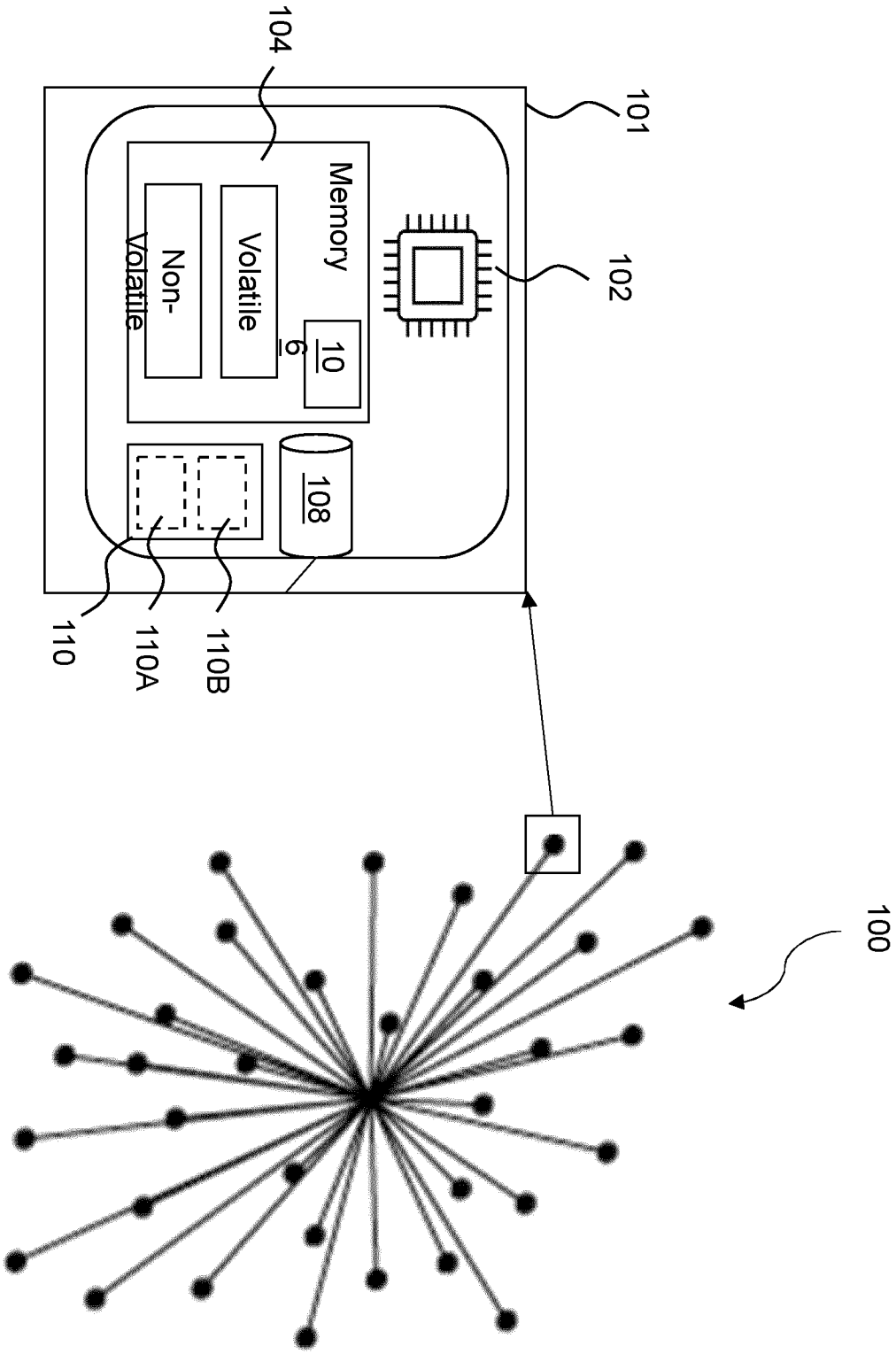

104
101
Memory
Non-Volatile
Volatile
106
102
108
110
110A
110B
100

Fig. 3b

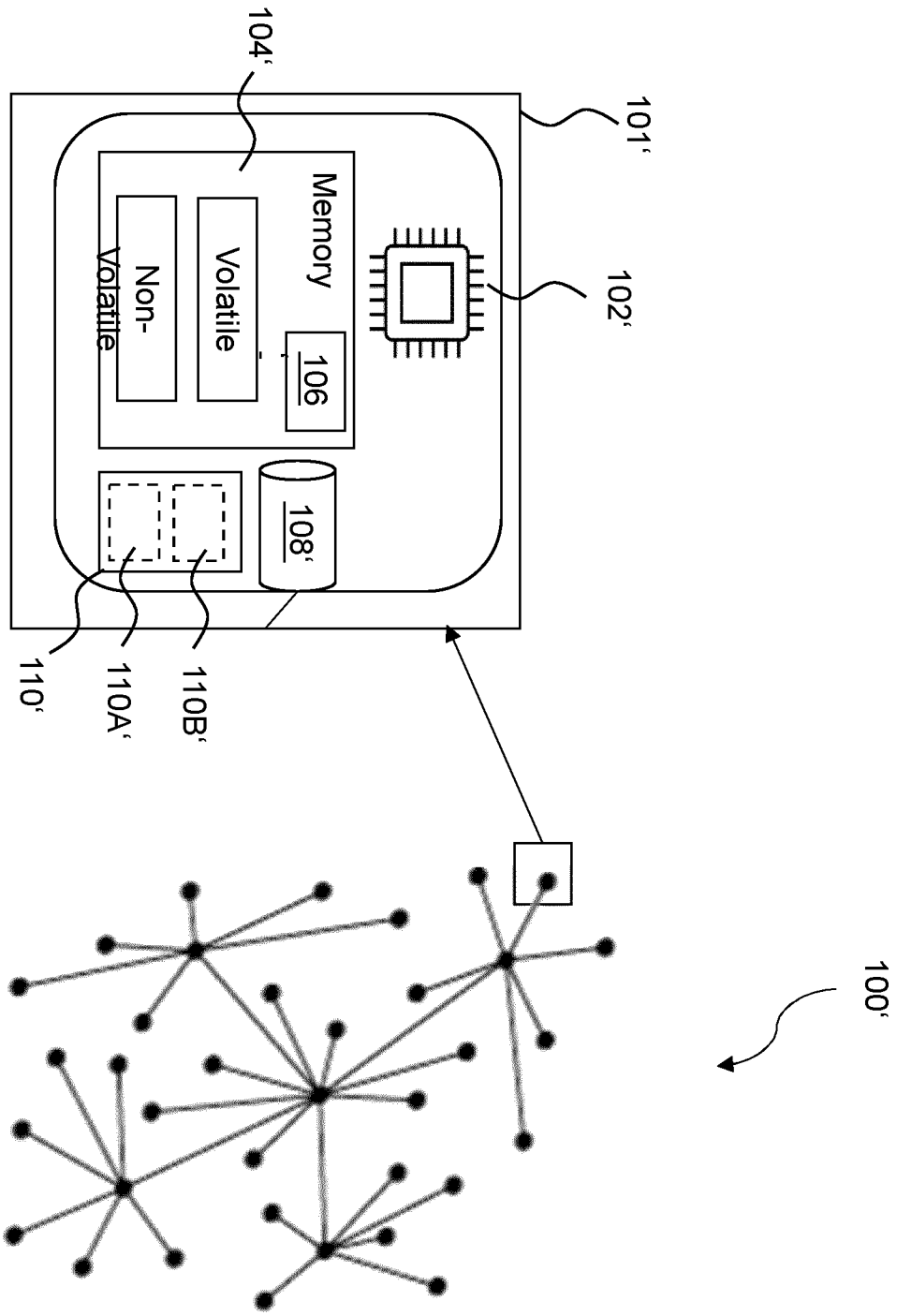
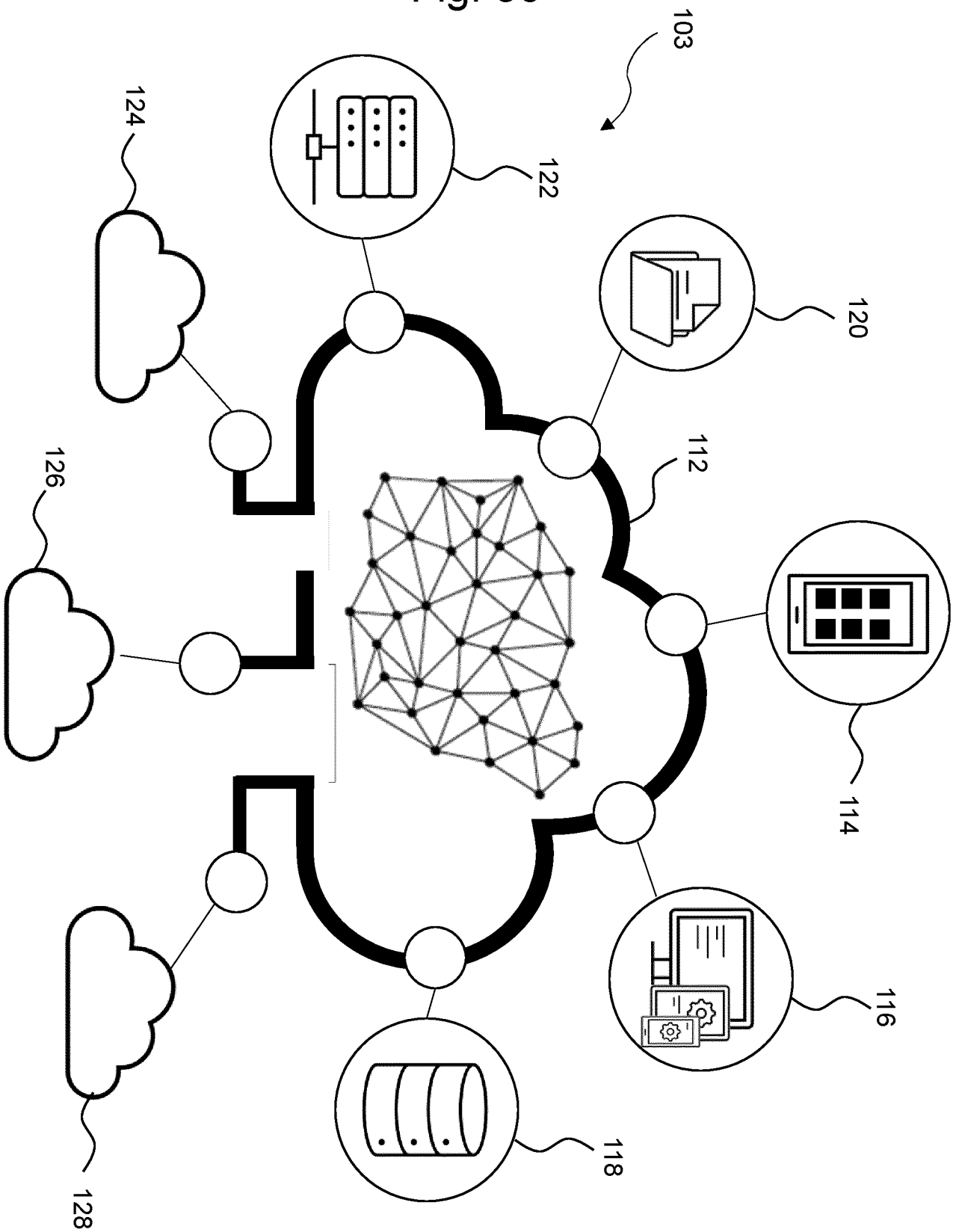

104'
101'
Memory
Non-Volatile
Volatile
106
102'
108'
110'
110A'
110B'
100'

Fig. 3c



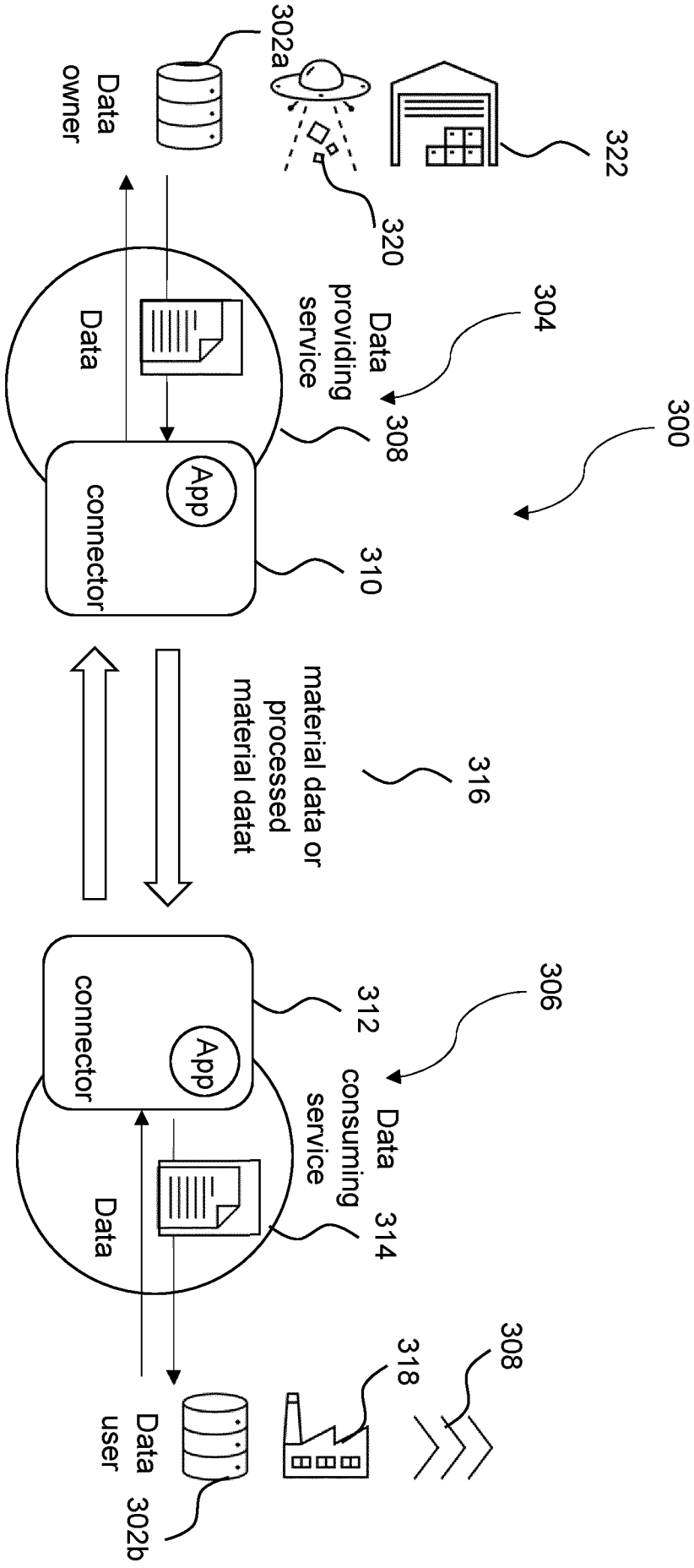

302a
Data owner
322
320
304
Data providing service
308
300
Data
App
connector
310
material data or processed material datat
316
306
312
App
connector
Data consuming service
314
Data
308
318
Data user
302b

Fig. 3d

Fig. 4

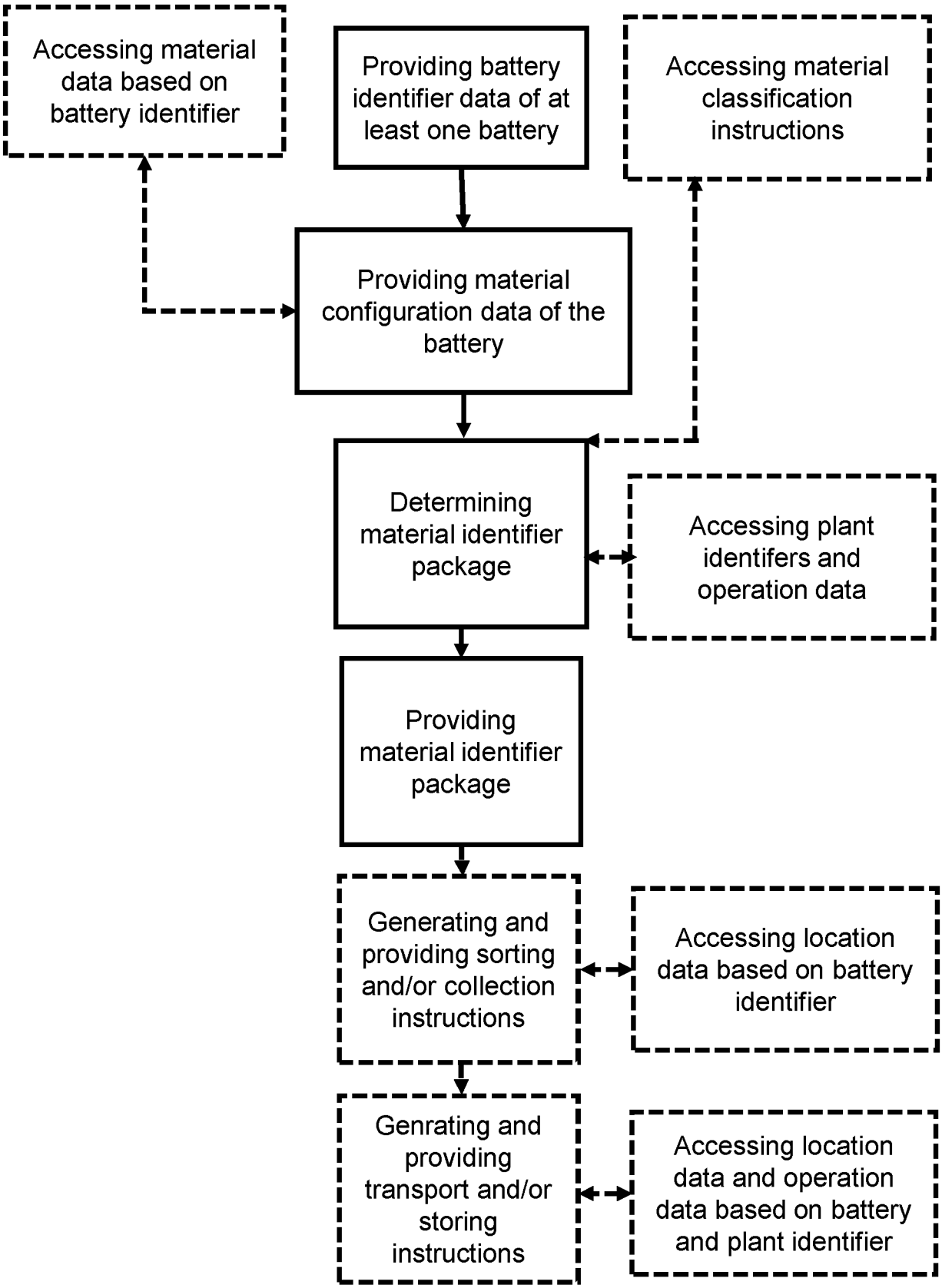

Accessing material data based on battery identifier
Providing battery identifier data of at least one battery
Accessing material classification instructions
Providing material configuration data of the battery
Determining material identifier package
Accessing plant identifers and operation data
Providing material identifier package
Generating and providing sorting and/or collection instructions
Accessing location data based on battery identifier
Genrating and providing transport and/or storing instructions
Accessing location data and operation data based on battery and plant identifier

Fig. 5

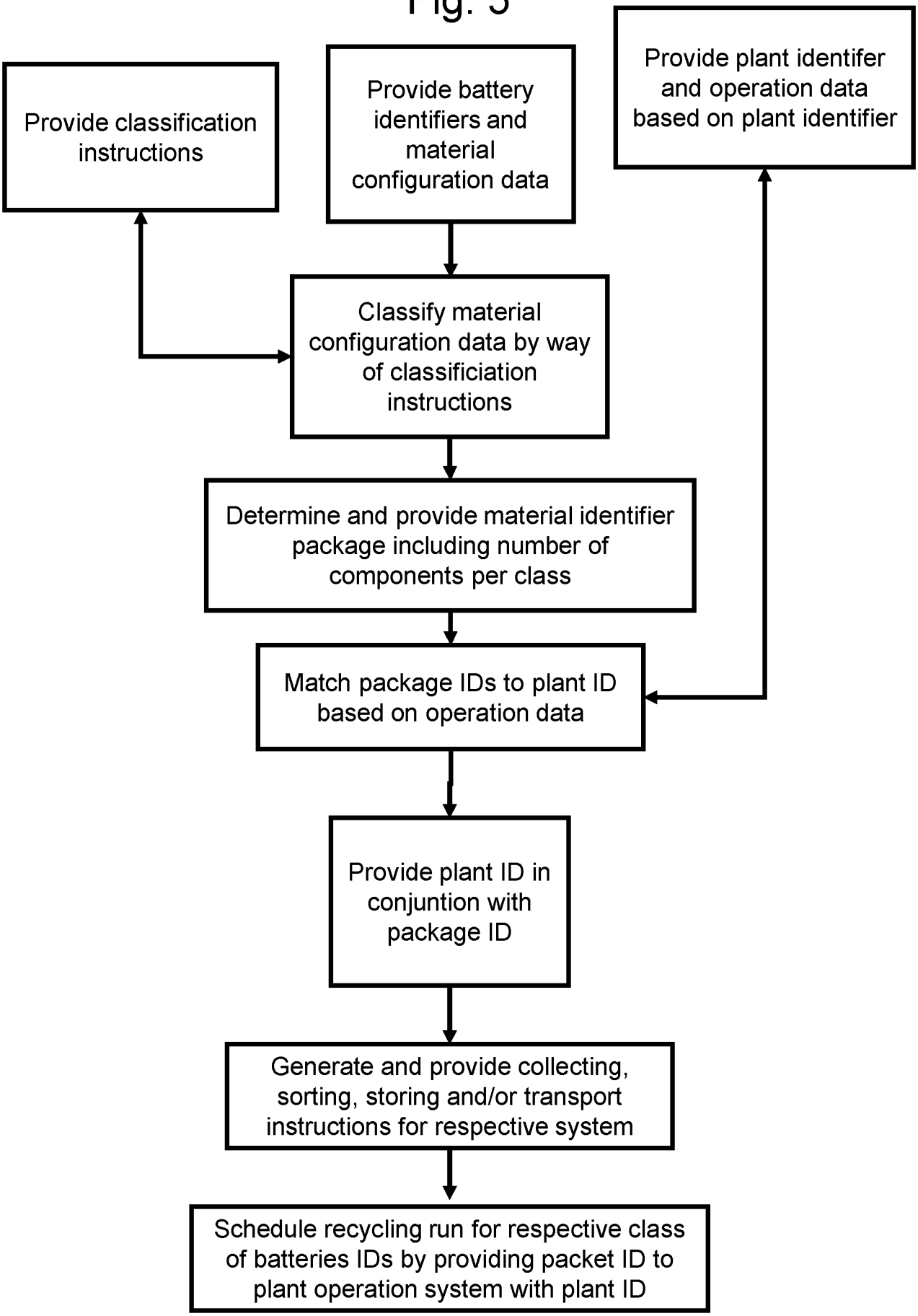

Provide classification instructions
Provide battery identifiers and material configuration data
Provide plant identifer and operation data based on plant identifier
Classify material configuration data by way of classificiation instructions
Determine and provide material identifier package including number of components per class
Match package IDs to plant ID based on operation data
Provide plant ID in conjuntion with package ID
Generate and provide collecting, sorting, storing and/or transport instructions for respective system
Schedule recycling run for respective class of batteries IDs by providing packet ID to plant operation system with plant ID

Fig. 6

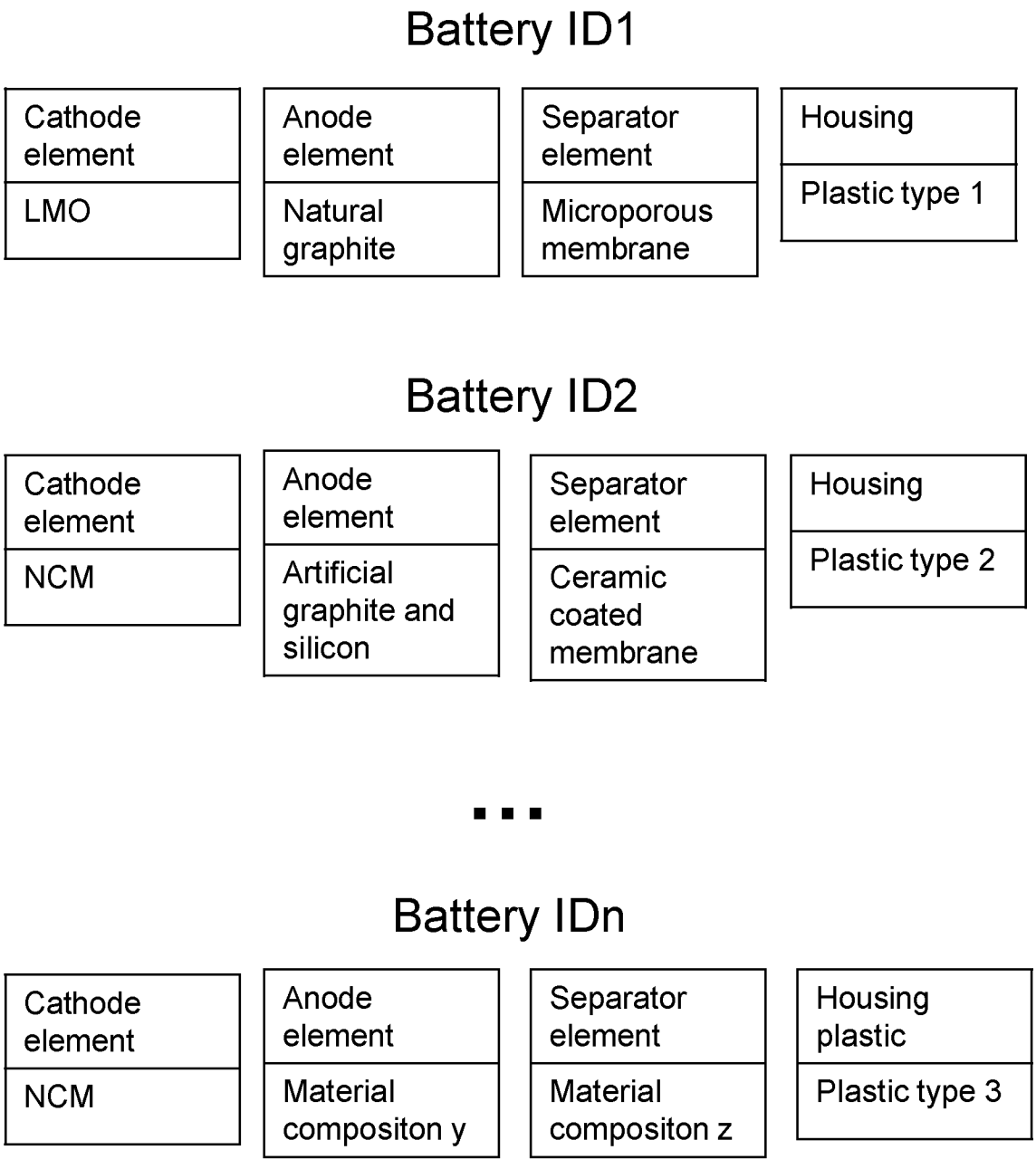

Battery ID1
Cathode element
LMO
Anode element
Natural graphite
Separator element
Microporous membrane
Housing
Plastic type 1
Battery ID2
Cathode element
NCM
Anode element
Artificial graphite and silicon
Separator element
Ceramic coated membrane
Housing
Plastic type 2
Battery IDn
Cathode element
NCM
Anode element
Material compositon y
Separator element
Material compositon z
Housing plastic
Plastic type 3

Fig. 7

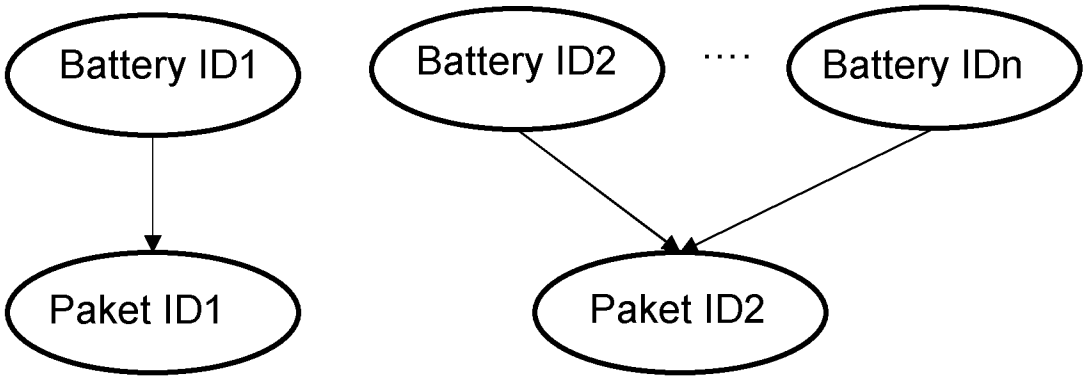


Fig. 8

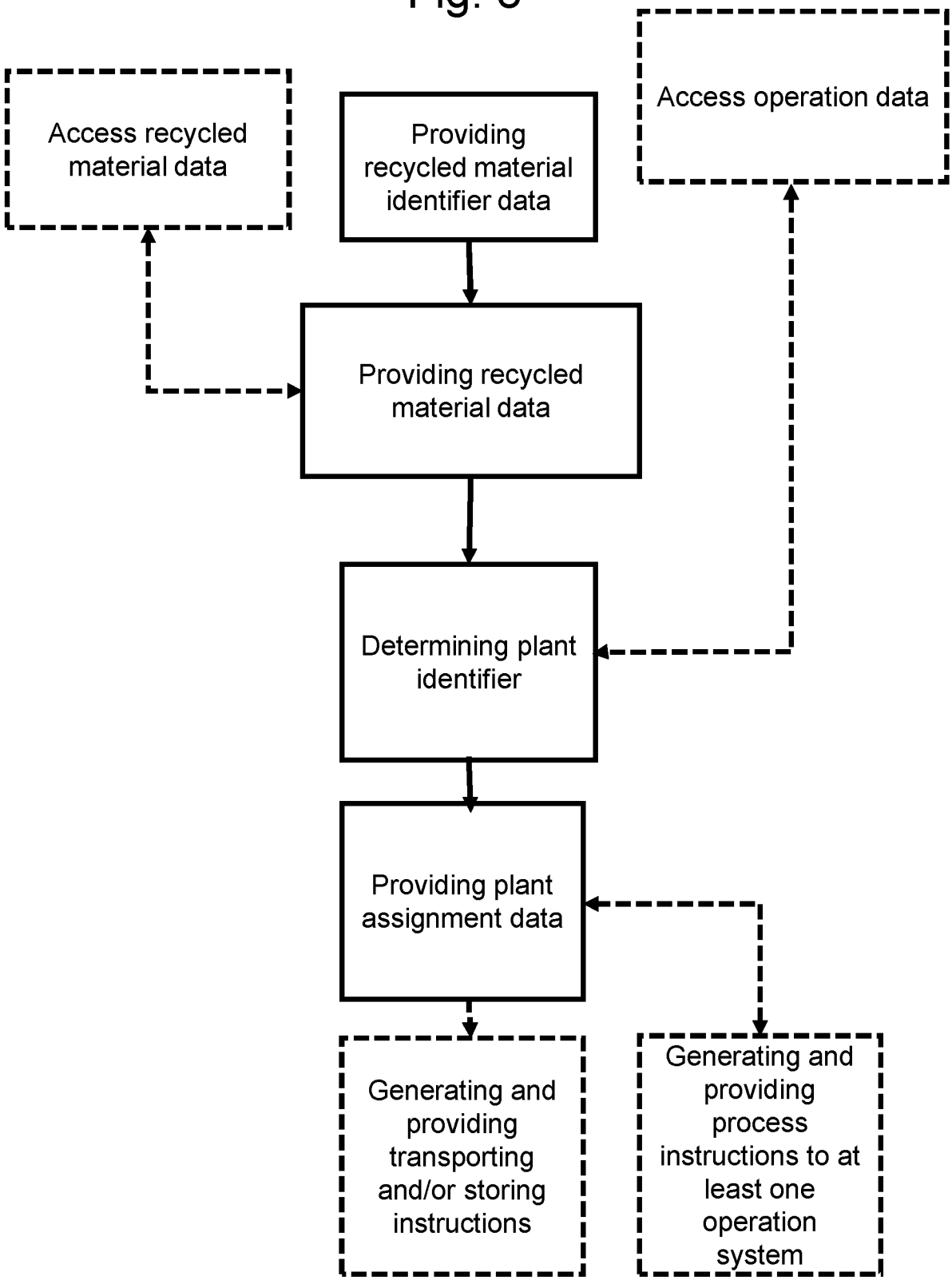

Access recycled material data
Providing recycled material identifier data
Access operation data
Providing recycled material data
Determining plant identifier
Providing plant assignment data
Generating and providing transporting and/or storing instructions
Generating and providing process instructions to at least one operation system

Fig. 9

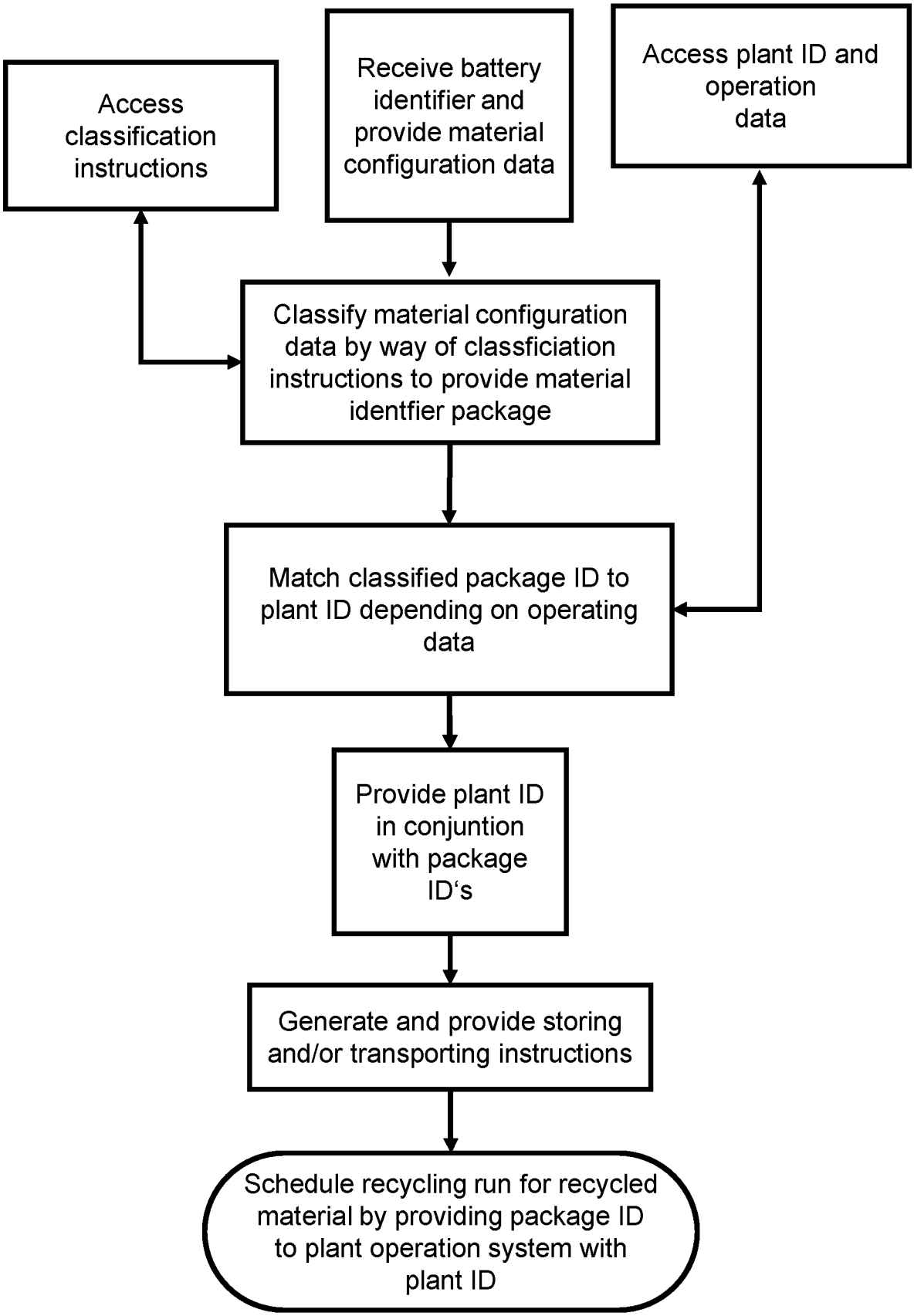

Access classification instructions
Receive battery identifier and provide material configuration data
Access plant ID and operation data
Classify material configuration data by way of classficiation instructions to provide material identfier package
Match classified package ID to plant ID depending on operating data
Provide plant ID in conjuntion with package ID‘s
Generate and provide storing and/or transporting instructions
Schedule recycling run for recycled material by providing package ID to plant operation system with plant ID

Fig. 10

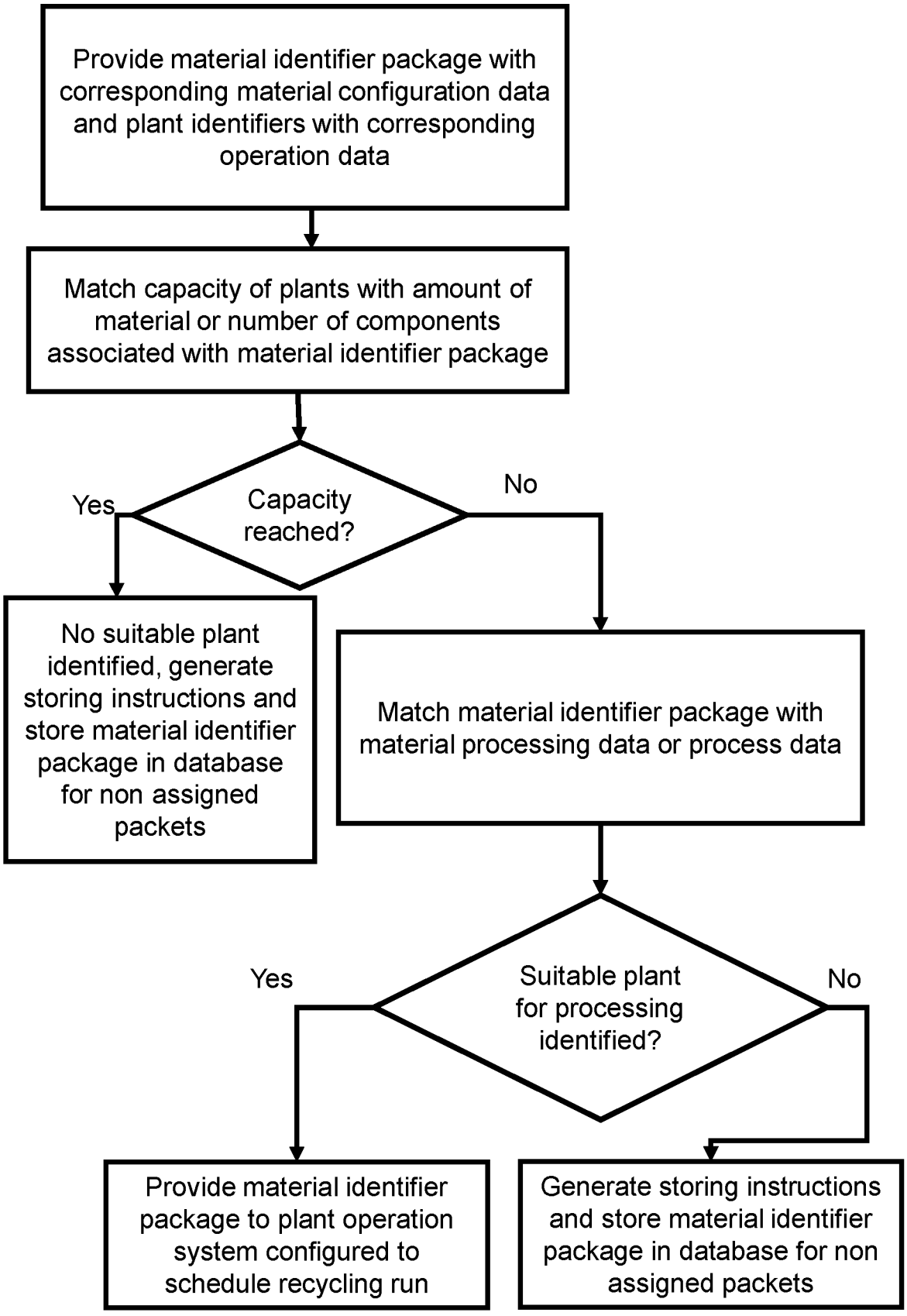

Provide material identifier package with corresponding material configuration data and plant identifiers with corresponding operation data
Match capacity of plants with amount of material or number of components associated with material identifier package
Capacity reached?
Yes
No
No suitable plant identified, generate storing instructions and store material identifier package in database for non assigned packets
Match material identifier package with material processing data or process data
Suitable plant for processing identified?
Yes
No
Provide material identifier package to plant operation system configured to schedule recycling run
Generate storing instructions and store material identifier package in database for non assigned packets

Fig. 11

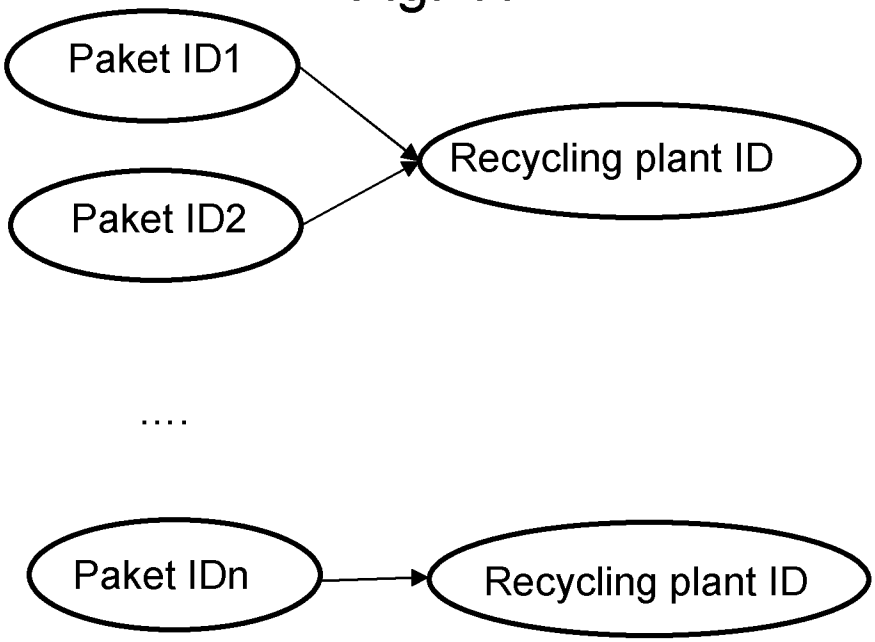


Fig. 12

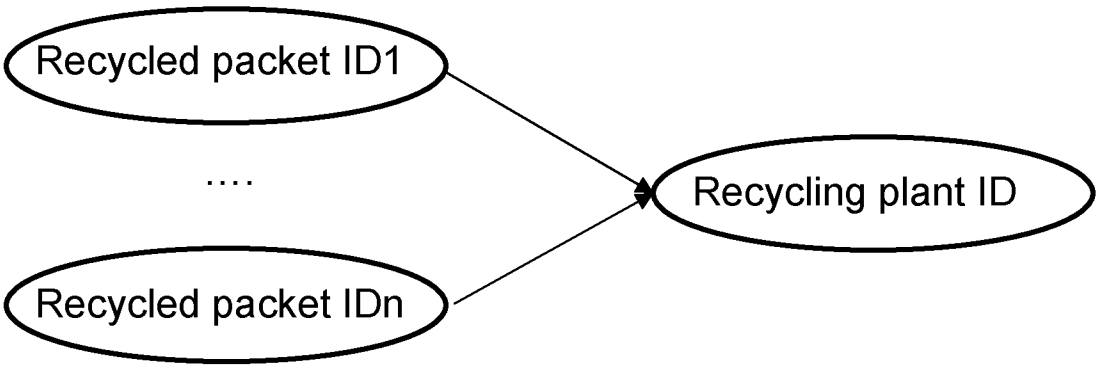


Fig. 13

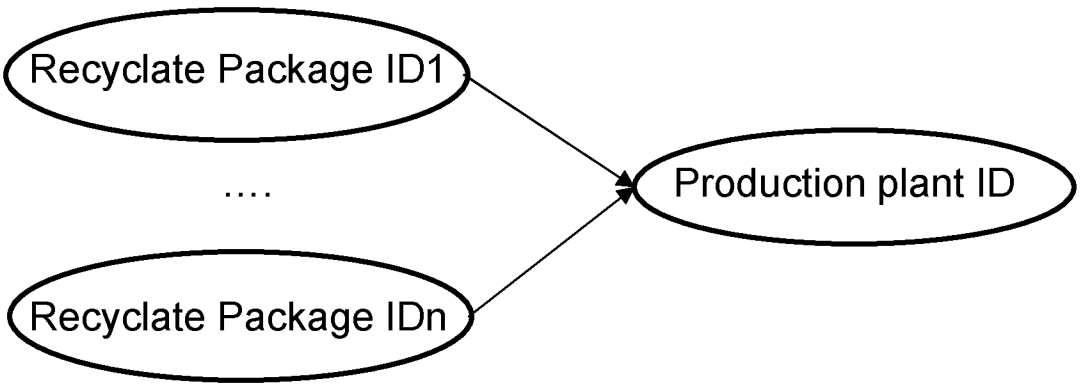


Fig. 14

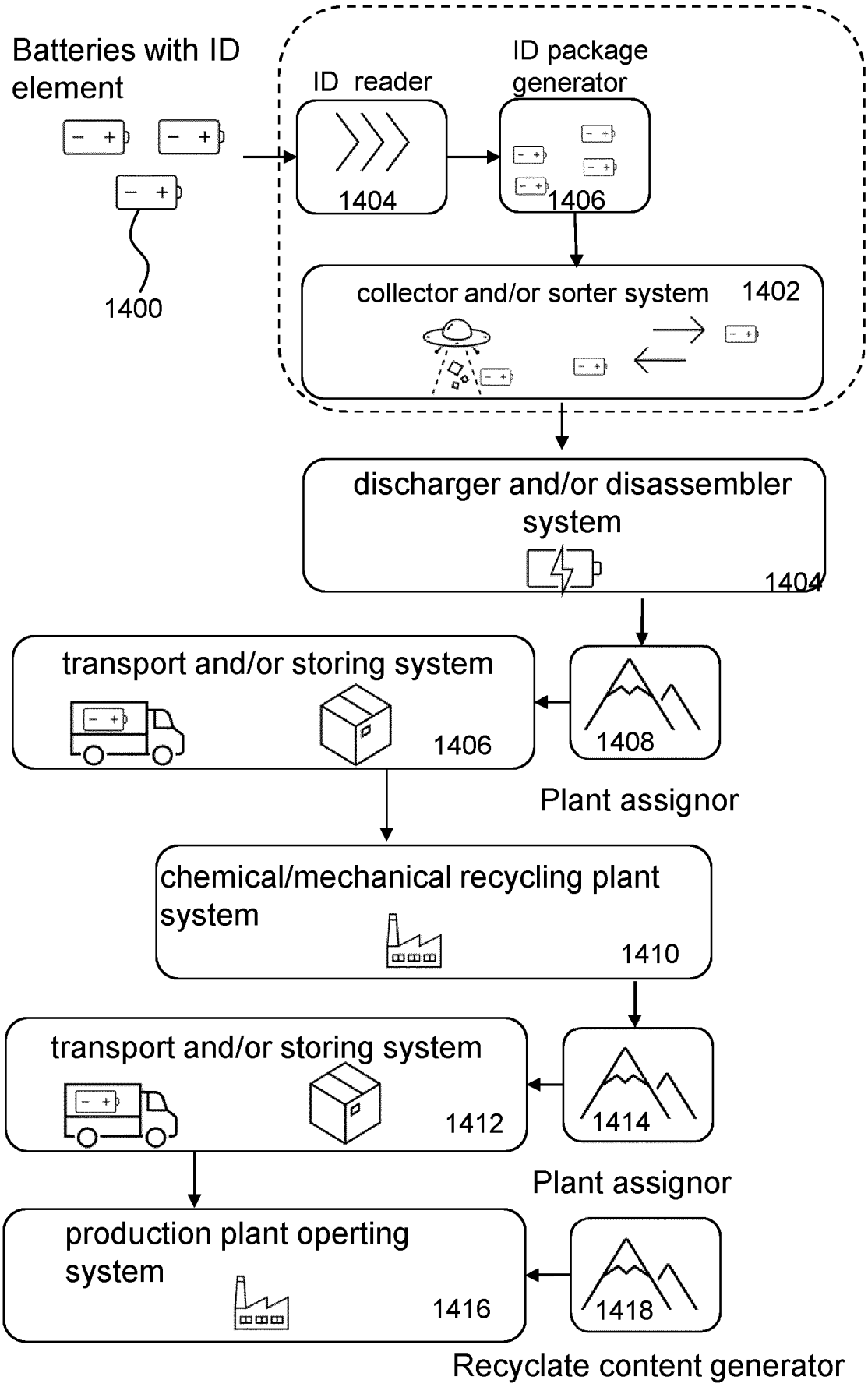

Batteries with ID element
1400
ID reader
1404
ID package generator
1406
collector and/or sorter system
1402
discharger and/or disassembler system
1404
transport and/or storing system
1406
1408
Plant assignor
chemical/mechanical recycling plant system
1410
transport and/or storing system
1412
1414
Plant assignor
production plant operting system
1416
1418
Recyclate content generator

Fig. 15

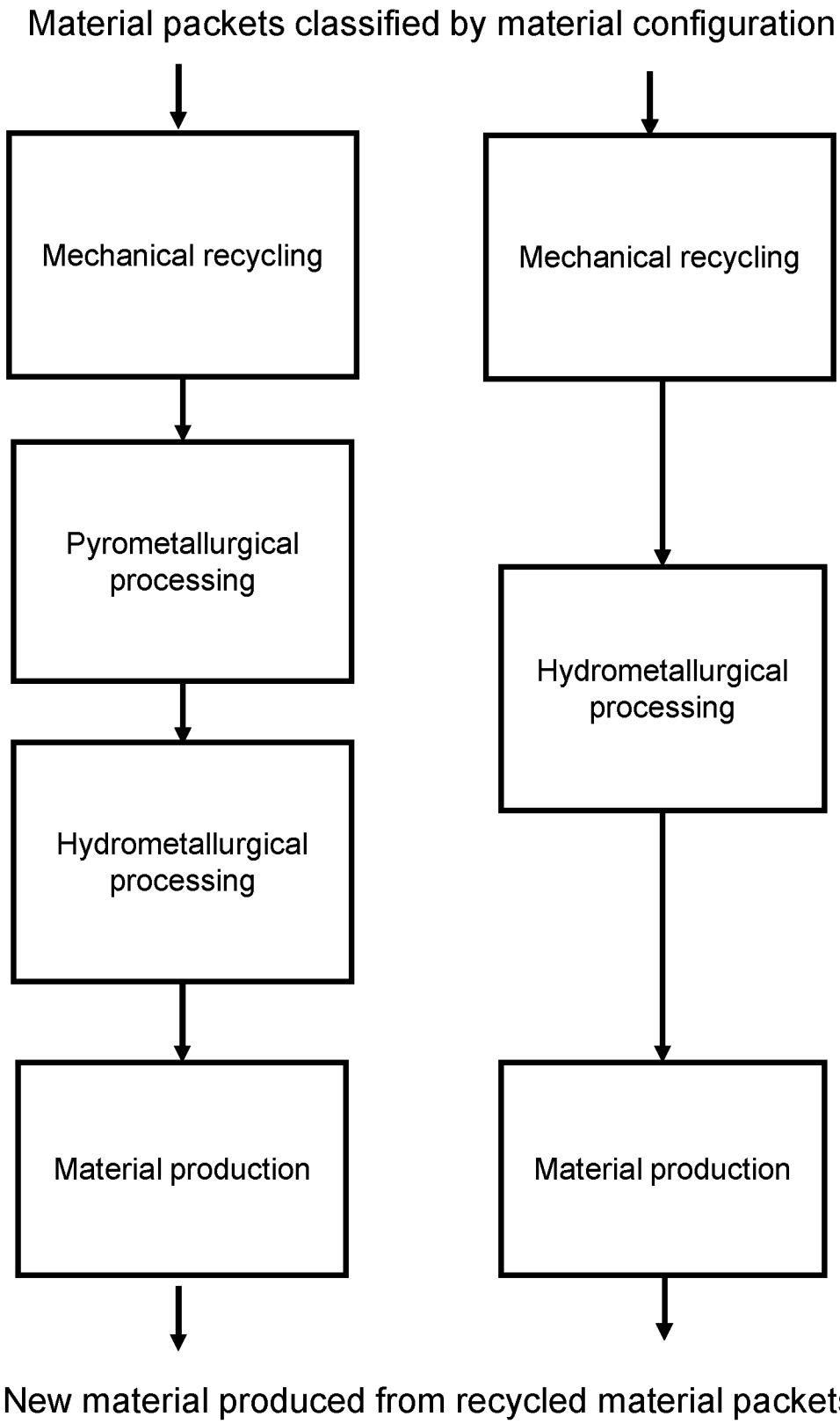

Material packets classified by material configuration
Mechanical recycling
Pyrometallurgical processing
Hydrometallurgical processing
Material production
Mechanical recycling
Hydrometallurgical processing
Material production
New material produced from recycled material packets

Fig. 16

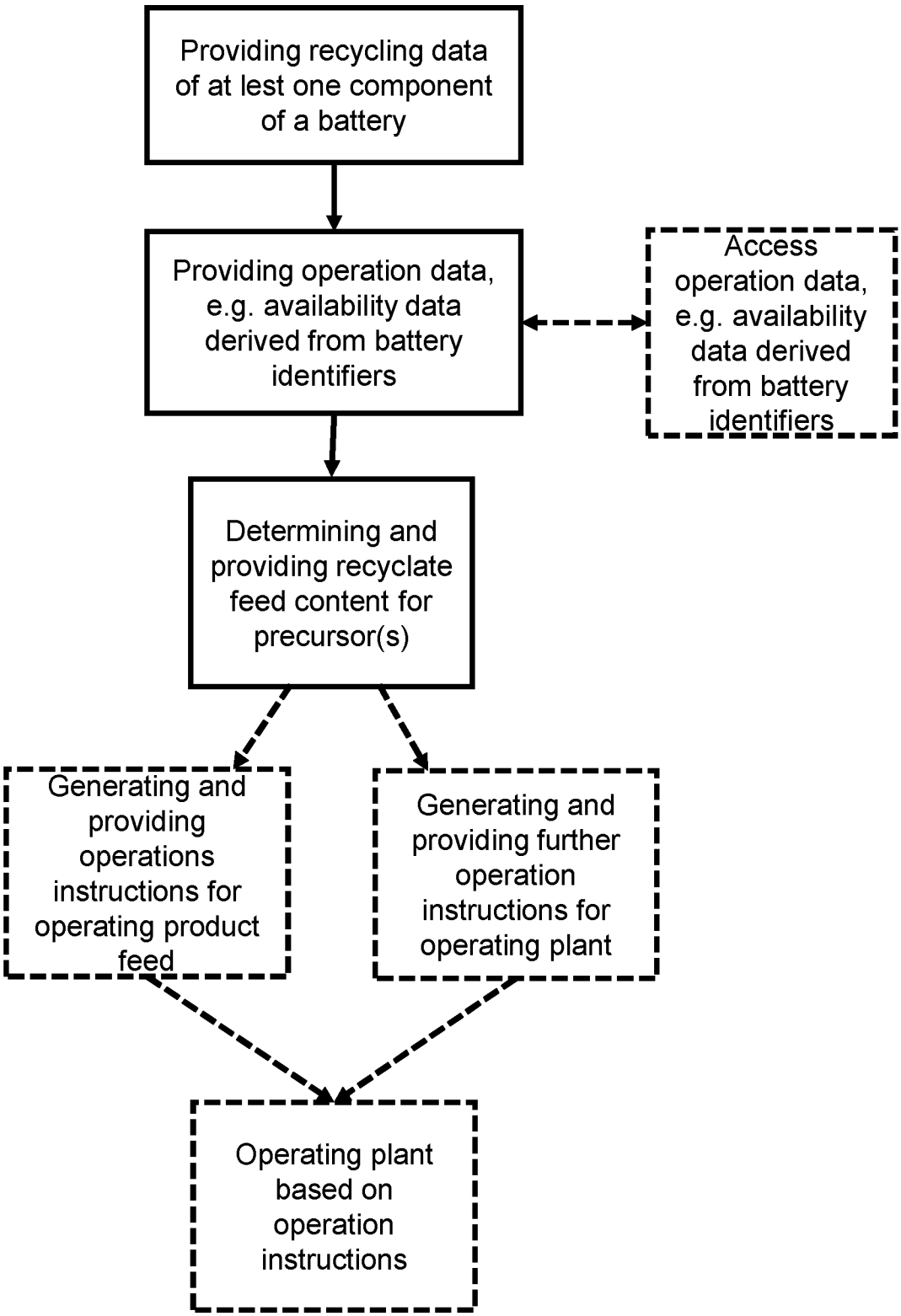

Providing recycling data of at lest one component of a battery
Providing operation data, e.g. availability data derived from battery identifiers
Access operation data, e.g. availability data derived from battery identifiers
Determining and providing recyclate feed content for precursor(s)
Generating and providing operations instructions for operating product feed
Generating and providing further operation instructions for operating plant
Operating plant based on operation instructions

Fig. 17

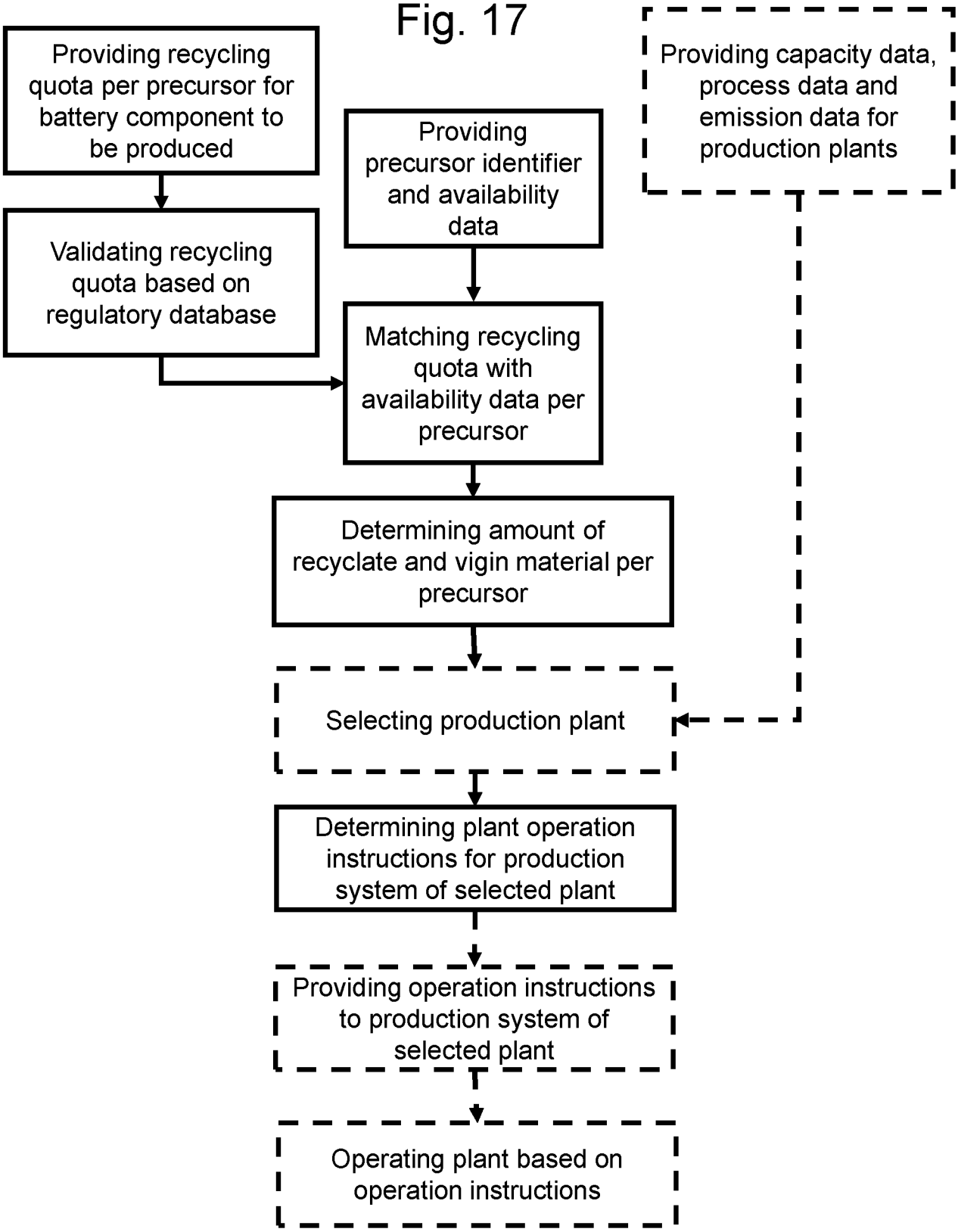

Providing recycling quota per precursor for battery component to be produced
Validating recycling quota based on regulatory database
Providing precursor identifier and availability data
Matching recycling quota with availability data per precursor
Providing capacity data, process data and emission data for production plants
Determining amount of recyclate and vigin material per precursor
Selecting production plant
Determining plant operation instructions for production system of selected plant
Providing operation instructions to production system of selected plant
Operating plant based on operation instructions

Fig. 18

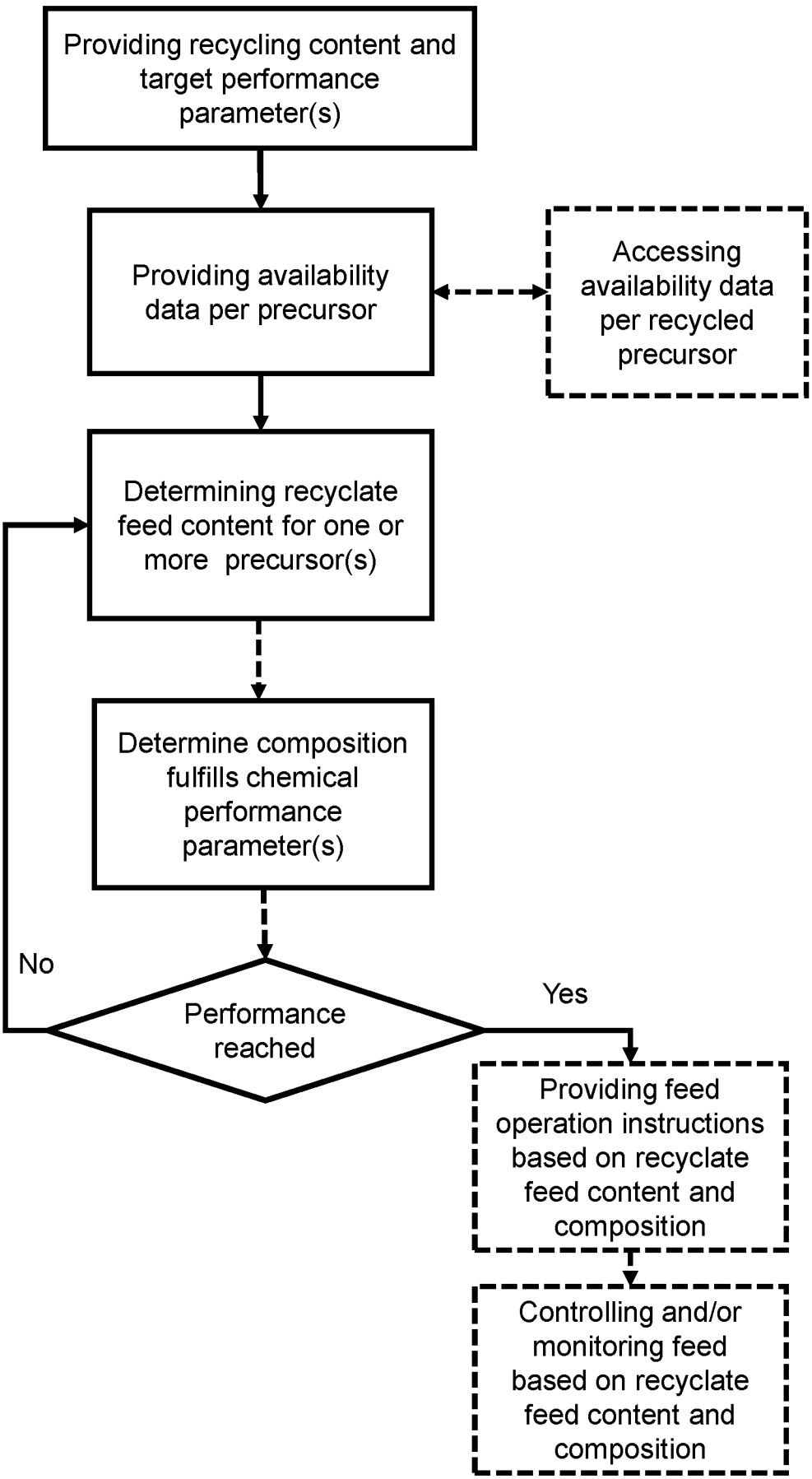

Providing recycling content and target performance parameter(s)
Providing availability data per precursor
Accessing availability data per recycled precursor
Determining recyclate feed content for one or more precursor(s)
Determine composition fulfills chemical performance parameter(s)
No
Performance reached
Yes
Providing feed operation instructions based on recyclate feed content and composition
Controlling and/or monitoring feed based on recyclate feed content and composition

Fig. 19

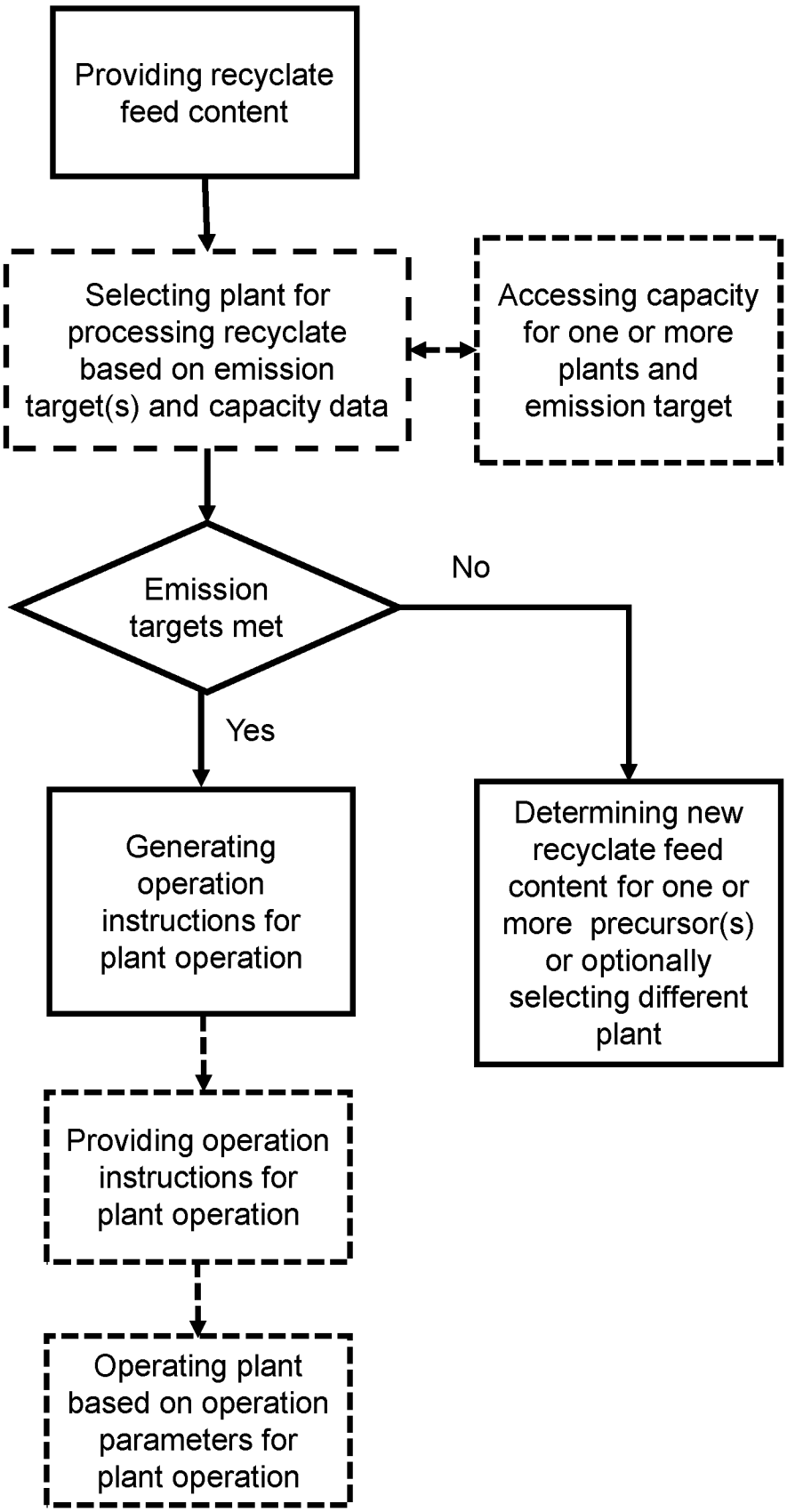

Providing recyclate feed content
Selecting plant for processing recyclate based on emission target(s) and capacity data
Accessing capacity for one or more plants and emission target
Emission targets met
No
Yes
Generating operation instructions for plant operation
Determining new recyclate feed content for one or more precursor(s) or optionally selecting different plant
Providing operation instructions for plant operation
Operating plant based on operation parameters for plant operation

Fig. 20

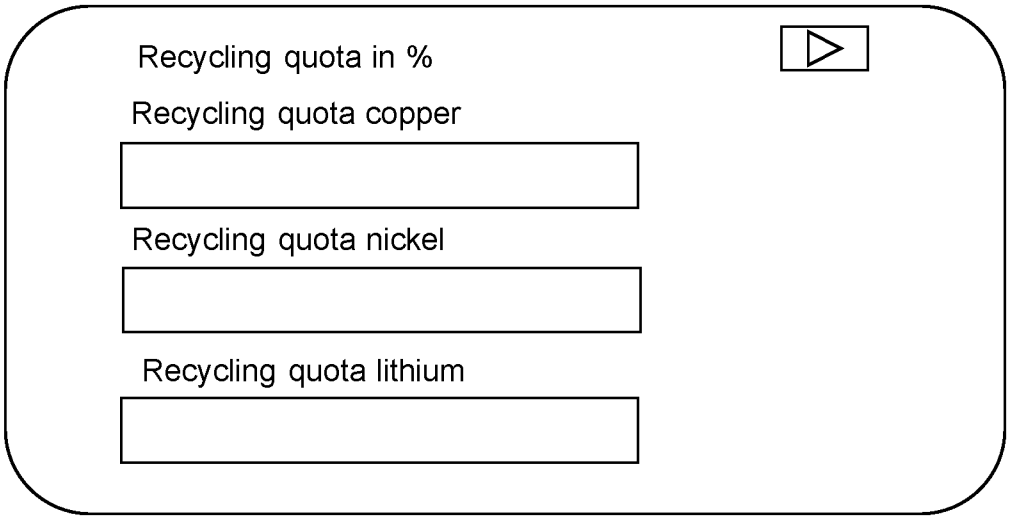


Fig. 21

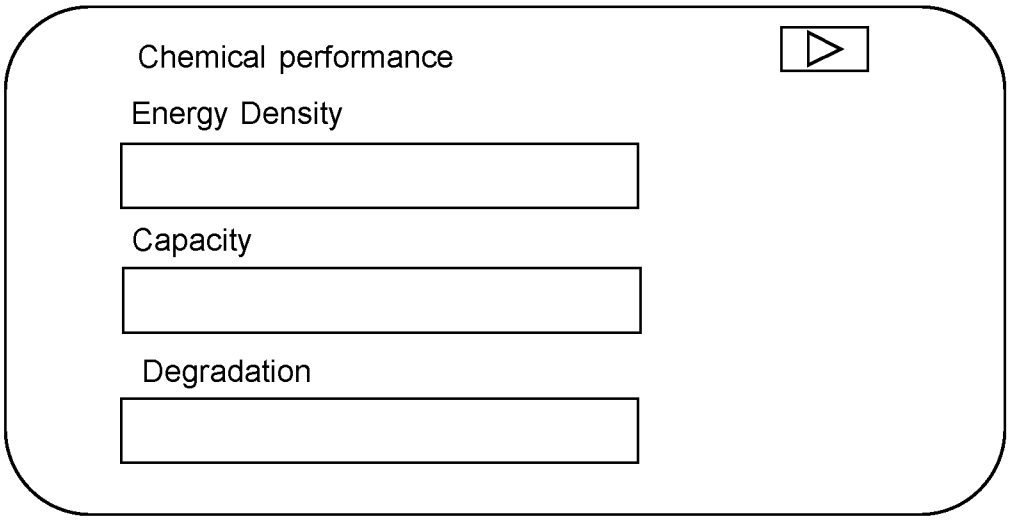
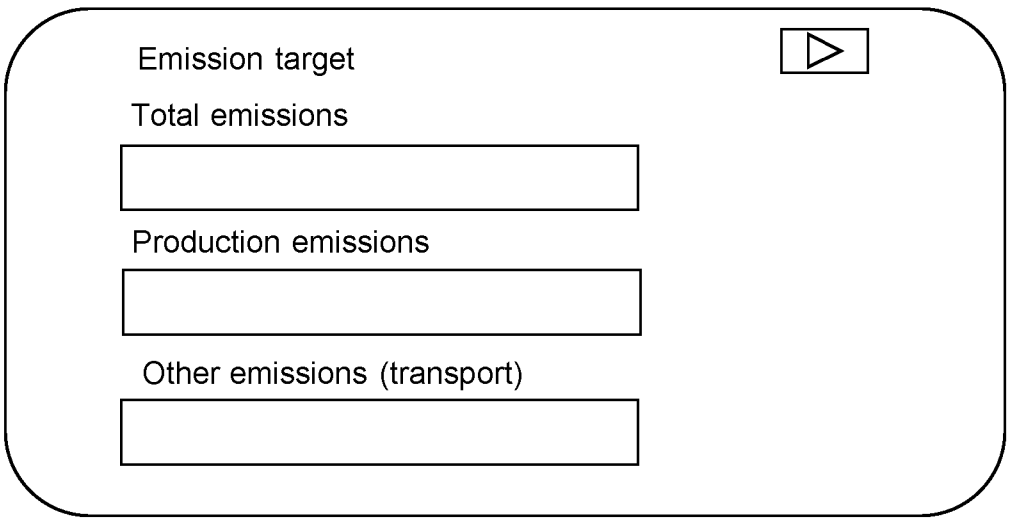


Fig. 22



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2023/056908

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06Q10/30 G06Q10/08 H04L9/00
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G06Q H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2016/371658 A1 (BORGES GABRIEL P [BR] ET AL) 22 December 2016 (2016-12-22) the whole document -----	1-15
X	US 2011/225098 A1 (WOLFF PAUL KENNETH [US] ET AL) 15 September 2011 (2011-09-15) figures 1, 4A, 4F, 6, 7A paragraph [0038] paragraph [0041] - paragraph [0050] paragraph [0056] paragraph [0068] paragraph [0077] - paragraph [0078] paragraph [0090] ----- -/--	1-15

[x] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 May 2023	06/06/2023

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Komnios, Ioannis

1

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INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2023/056908

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2021/198637 A1 (SONY GROUP CORP [JP]; SONY EUROPE BV [GB]) 7 October 2021 (2021-10-07) figures 10-16 page 6, line 37 - line 40 page 8, line 16 - line 21 page 10, line 14 - page 13, line 32	1-15

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2023/056908

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		US 2016069840 A1	10-03-2016
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US 2011225098 A1	15-09-2011	NONE	
WO 2021198637 A1	07-10-2021	EP 4115361 A1	11-01-2023
		GB 2593747 A	06-10-2021
		JP 2023519833 A	15-05-2023
		US 2023051115 A1	16-02-2023
		WO 2021198637 A1	07-10-2021