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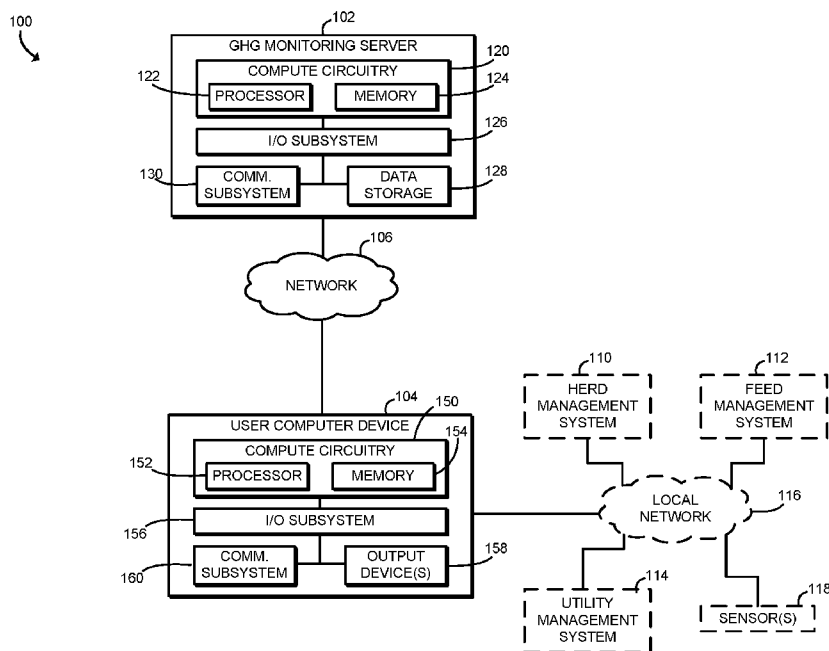


FIG. 1

(57) Abstract: Technologies for measuring greenhouse gas emissions in ruminants following administration of feed additives include receiving, by a server computer and for a reference time period of the cattle farm operation, feed ingredient usage data for each cattle type. The feed ingredient usage data includes an amount of feed provided for each cattle type and identification of a feed additive included in the feed. The feed additive is configured to reduce an amount of greenhouse gas emissions produced by each cattle of the cattle herd that consumes the feed. The server computer also determines, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using a model of total controllable greenhouse gas emissions with the feed ingredient usage data as an input to the model, which may be used to request a carbon credit.



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TECHNOLOGIES FOR MEASURING GREENHOUSE GAS EMISSIONS IN RUMINANTS FOLLOWING ADMINISTRATION OF FEED ADDITIVES

[0001] The present application claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Application Serial No. 63/536,816, which was filed on September 6, 2023, the entire disclosure of which is incorporated herein by reference.

CROSS-REFERENCE TO RELATED DISCLOSURE

[0002] Cross-reference is made to co-pending International Patent Application Serial No. PCT/US2024/045531, entitled “METHODS FOR MEASURING GREENHOUSE GAS EMISSIONS IN RUMINANTS FOLLOWING ADMINISTRATION OF FEED ADDITIVES,” which was filed on September 6, 2024, the entire disclosure of which is incorporated herein by reference.

FIELD OF THE DISCLOSURE

[0003] The present disclosure relates generally to technologies for measuring greenhouse gas emissions in ruminants following administration of feed additives and, more particularly, to technologies for monitoring and managing a carbon footprint of a cattle farm operation using a feed additive to obtain a carbon credit.

BACKGROUND

[0004] In the modern world, mechanisms for the reduction in greenhouse gas emissions are in high demand. The mechanisms being investigated are broad and far-reaching in nature. As a result, nearly every technological field has been challenged to consider steps in order to potentially reduce its “carbon footprint” in an effort to be environmentally conscious.

[0005] In the agriculture and food arenas, the reduction of greenhouse gases such as methane has been investigated. Various active ingredients that can be fed to animals have been explored in an effort to reduce greenhouse gas emissions such as methane that are expelled by the animals. In particular, feeding monensin (Rumensin™) and 3-nitrooxypropanol (Bovaer™) to an animal can result in reduction in greenhouse gas emissions from the animal, in particular ruminant animals. Furthermore, the availability of carbon credits provide an incentive for farmers and producers to reduce greenhouse gas emissions. Thus, there exists a need to maximize reduction of greenhouse gas emissions in the animal industry, such as cattle farms, in order to qualify for and obtain desirable carbon credits.

[0006] However, monitoring and managing greenhouse gas emissions resulting from certain industries, including cattle farms, can be challenging due to the complexity of managing the tracked inputs, challenges associated with accurately determining the greenhouse gas emissions, and the difficulty in verifying reduction in the greenhouse gas emissions due to remedial actions, such as the introduction of feed additives.

SUMMARY

[0007] According to an aspect of the present disclosure, a method for managing a carbon footprint of a cattle farm operation having a cattle herd comprising one or more cattle type may include receiving, by a server computer and for a reference time period of the cattle farm operation, feed ingredient usage data for each cattle type of the cattle herd, wherein the feed ingredient usage data includes an amount of feed provided for each cattle type of the cattle herd and identification of a feed additive included in the feed, and wherein the feed additive is configured to reduce an amount of greenhouse gas emissions produced by each cattle of the cattle herd that consumes the feed. The method may also include determining, by the server computer and for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using a model of total controllable greenhouse gas emissions with the feed ingredient usage data as an input to the model. Additionally, the method may include requesting, by the server computer and for the reference time period of the cattle farm operation, a carbon credit based on the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation.

[0008] In some embodiments, the feed additive may be embodied as monensin. Additionally or alternatively, the feed additive may be embodied as 3-nitrooxypropanol. In some embodiments, the greenhouse gas emissions may include methane. Additionally, in some embodiments, the cattle herd may include dairy cattle and/or beef cattle.

[0009] In some embodiments, the feed additive may be configured to reduce the amount of greenhouse emissions produced by each cattle of the cattle herd that consumes the feed by reducing enteric fermentation of each cattle. Additionally or alternatively, the feed additive may be configured to reduce the amount of greenhouse emissions produced by each cattle of the cattle herd that consumes the feed by decreasing dry matter intake (DMI) of each cattle. In some embodiments, the amount of feed provided for each cattle type comprises a plurality of ingredients and a corresponding amount of each ingredient of the plurality of ingredients.

[0010] Additionally, in some embodiments, the method may further comprise receiving, by the server computer and for the reference time period of the cattle farm operation, utility usage data indicative of an amount of a utility service used by the cattle farm operation. In such embodiments, determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable greenhouse gas emissions with (i) the feed ingredient usage data and (ii) the utility usage data as inputs to the model. In such embodiments, receiving the utility usage data may include receiving a percentage of usage of the utility service used for dairy operations of the cattle farm operation.

[0011] Furthermore, in some embodiments, the method may include receiving, by the server computer and for the reference time period of the cattle farm operation, herd demographics data indicative of the population and breed of the cattle herd. In such embodiments, determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable greenhouse gas emissions with (i) the feed ingredient usage data, (ii) the utility usage data, and (iii) the herd demographics data as inputs to the model. In such embodiments, receiving the herd demographics data may include receiving sales data indicative of a number of cattle sold from the cattle herd.

[0012] Additionally, in some embodiments, the method may further include receiving, by a server computer and for the reference time period of the cattle farm operation, milk production data that identifies an amount of milk type produced by each lactating cattle type of the cattle herd. In such embodiments, determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable greenhouse gas emissions with (i) the feed ingredient usage data, (ii) the utility usage data, (iii) the herd demographics data, and (iv) the milk production data as inputs to the model.

[0013] In some embodiments, determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include determining, by the server computer and for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation and determining, by the server computer and for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to feed cultivation.

[0014] Additionally, in some embodiments, determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include determining, by the server computer and for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd and determining, by the server computer and for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd.

[0015] In some embodiments, determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include determining, by the server computer and for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to manure management of the cattle farm operation and determining, by the server computer and for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to manure management of the cattle farm operation.

[0016] Additionally, in some embodiments, determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include determining, by the server computer and for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation and determining, by the server computer and for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation.

[0017] Furthermore, in some embodiments, determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include determining, by the server computer and for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation; determining, by the server computer and for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd; determining, by the server computer and for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to manure management of the cattle farm operation; determining, by the server computer and for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to utility usage of the cattle

farm operation; and determining, by the server computer and for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on (i) the estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation, (ii) the estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd, (iii) the estimated amount of greenhouse gas emission due to manure management of the cattle farm operation, and (iv) the estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation.

[0018] Additionally, in some embodiments, determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include allocating the estimated total amount of controllable greenhouse gas emissions between milk production operations of the cattle farm operation and meat production operations of the cattle farm operation. In such embodiments, determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may further include allocating utility usage indicative of an amount of utility service used by the cattle farm operation based on cattle type of the cattle herd.

[0019] In some embodiments, requesting the carbon credit may include determining a reduction of greenhouse gas emissions based on the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation and a baseline greenhouse gas emissions amount. In such embodiments, the method may also include requesting, by the server computer and for the reference time period of the cattle farm operation, the carbon credit based on the determined reduction of greenhouse gas emissions.

[0020] Additionally, in some embodiments, the method may include generating greenhouse gas emissions metrics based on the estimated total amount of controllable greenhouse gas emissions and displaying the greenhouse gas emissions metrics to a user. In such embodiments, the greenhouse gas emissions metrics may include indicia of a comparison of the estimated total amount of controllable greenhouse gas emissions for the reference time period and a prior time period. Additionally, in such embodiments, the estimated total amount of controllable greenhouse gas emissions may include a plurality of greenhouse gas emission types and wherein the greenhouse gas emissions metrics identifies an amount of each greenhouse gas emission type. Furthermore, in some embodiments, the method may include determining a recommended greenhouse gas emission remediation action for the cattle farm operation based on the estimated total amount of controllable greenhouse gas emissions.

[0021] According to another aspect of the present disclosure, a server computer for managing a carbon footprint of a cattle farm operation having a cattle herd comprising one or more cattle type may include a processor and a memory having stored therein a plurality of instructions that, when executed by the processor, cause the server computer to receive, for a reference time period of the cattle farm operation, feed ingredient usage data for each cattle type of the cattle herd, wherein the feed ingredient usage data includes an amount of feed provided for each cattle type of the cattle herd and identification of a feed additive included in the feed, and wherein the feed additive is configured to reduce an amount of greenhouse gas emissions produced by each cattle of the cattle herd that consumes the feed. The plurality of instructions may further cause the server computer to determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using a model of total controllable greenhouse gas emissions with the feed ingredient usage data as an input to the model. Additionally, the plurality of instructions may further cause the server computer to request, for the reference time period of the cattle farm operation, a carbon credit based on the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation.

[0022] In some embodiments, the feed additive may be embodied as monensin. Additionally or alternatively, the feed additive may be embodied as 3-nitrooxypropanol. In some embodiments, the greenhouse gas emissions may include methane. Additionally, in some embodiments, the cattle herd may include dairy cattle and/or beef cattle.

[0023] In some embodiments, the feed additive may be configured to reduce the amount of greenhouse emissions produced by each cattle of the cattle herd that consumes the feed by reducing enteric fermentation of each cattle. Additionally or alternatively, the feed additive may be configured to reduce the amount of greenhouse emissions produced by each cattle of the cattle herd that consumes the feed by decreasing dry matter intake (DMI) of each cattle. In some embodiments, the amount of feed provided for each cattle type comprises a plurality of ingredients and a corresponding amount of each ingredient of the plurality of ingredients.

[0024] Additionally, in some embodiments, the plurality of instructions may further cause the server computer to receive, for the reference time period of the cattle farm operation, utility usage data indicative of an amount of a utility service used by the cattle farm operation. In such embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable

greenhouse gas emissions with (i) the feed ingredient usage data and (ii) the utility usage data as inputs to the model. In such embodiments, to receive the utility usage data may include to receive a percentage of usage of the utility service used for dairy operations of the cattle farm operation.

[0025] Furthermore, in some embodiments, the plurality of instructions may further cause the server computer to receive, for the reference time period of the cattle farm operation, herd demographics data indicative of the population and breed of the cattle herd. In such embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable greenhouse gas emissions with (i) the feed ingredient usage data, (ii) the utility usage data, and (iii) the herd demographics data as inputs to the model. In such embodiments, to receive the herd demographics data may include to receive sales data indicative of a number of cattle sold from the cattle herd.

[0026] Additionally, in some embodiments, the plurality of instructions may further cause the server computer to receive, for the reference time period of the cattle farm operation, milk production data that identifies an amount of milk type produced by each lactating cattle type of the cattle herd. In such embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable greenhouse gas emissions with (i) the feed ingredient usage data, (ii) the utility usage data, (iii) the herd demographics data, and (iv) the milk production data as inputs to the model.

[0027] In some embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation and to determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to feed cultivation.

[0028] Additionally, in some embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd and determining, by the server computer

and for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd.

[0029] In some embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to manure management of the cattle farm operation and to determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to manure management of the cattle farm operation.

[0030] Additionally, in some embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation and to determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation.

[0031] Furthermore, in some embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation; to determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd; to determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to manure management of the cattle farm operation; to determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation; and to determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on (i) the estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation, (ii) the estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd, (iii) the estimated amount of greenhouse gas emission due to manure management of the cattle farm operation, and (iv) the estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation.

[0032] Additionally, in some embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to allocate the estimated total amount of controllable greenhouse gas emissions between milk production operations of the cattle farm operation and meat production operations of the cattle farm operation. In such embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may further include to allocate utility usage indicative of an amount of utility service used by the cattle farm operation based on cattle type of the cattle herd.

[0033] In some embodiments, to request the carbon credit may include to determine a reduction of greenhouse gas emissions based on the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation and a baseline greenhouse gas emissions amount. In such embodiments, the plurality of instructions may further cause the server computer to request, for the reference time period of the cattle farm operation, the carbon credit based on the determined reduction of greenhouse gas emissions.

[0034] Additionally, in some embodiments, the plurality of instructions may further cause the server computer to generate greenhouse gas emissions metrics based on the estimated total amount of controllable greenhouse gas emissions and displaying the greenhouse gas emissions metrics to a user. In such embodiments, the greenhouse gas emissions metrics may include indicia of a comparison of the estimated total amount of controllable greenhouse gas emissions for the reference time period and a prior time period. Additionally, in such embodiments, the estimated total amount of controllable greenhouse gas emissions may include a plurality of greenhouse gas emission types and the greenhouse gas emissions metrics may identify an amount of each greenhouse gas emission type. Furthermore, in some embodiments, the plurality of instructions may further cause the server computer to determine a recommended greenhouse gas emission remediation action for the cattle farm operation based on the estimated total amount of controllable greenhouse gas emissions.

[0035] According to a further aspect of the present disclosure, one or more non-transitory, computer-readable storage media may include a plurality of instructions that, in response to execution, cause a server computer to receive, for a reference time period of the cattle farm operation, feed ingredient usage data for each cattle type of the cattle herd, wherein the feed ingredient usage data includes an amount of feed provided for each cattle type of the cattle herd and identification of a feed additive included in the feed, and wherein the feed additive is configured to reduce an amount of greenhouse gas emissions produced by each cattle of the cattle

herd that consumes the feed. The plurality of instructions may further cause the server computer to determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using a model of total controllable greenhouse gas emissions with the feed ingredient usage data as an input to the model. Additionally, the plurality of instructions may further cause the server computer to request, for the reference time period of the cattle farm operation, a carbon credit based on the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation.

[0036] In some embodiments, the feed additive may be embodied as monensin. Additionally or alternatively, the feed additive may be embodied as 3-nitrooxypropanol. In some embodiments, the greenhouse gas emissions may include methane. Additionally, in some embodiments, the cattle herd may include dairy cattle and/or beef cattle.

[0037] In some embodiments, the feed additive may be configured to reduce the amount of greenhouse emissions produced by each cattle of the cattle herd that consumes the feed by reducing enteric fermentation of each cattle. Additionally or alternatively, the feed additive may be configured to reduce the amount of greenhouse emissions produced by each cattle of the cattle herd that consumes the feed by decreasing dry matter intake (DMI) of each cattle. In some embodiments, the amount of feed provided for each cattle type comprises a plurality of ingredients and a corresponding amount of each ingredient of the plurality of ingredients.

[0038] Additionally, in some embodiments, the plurality of instructions may further cause the server computer to receive, for the reference time period of the cattle farm operation, utility usage data indicative of an amount of a utility service used by the cattle farm operation. In such embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable greenhouse gas emissions with (i) the feed ingredient usage data and (ii) the utility usage data as inputs to the model. In such embodiments, to receive the utility usage data may include to receive a percentage of usage of the utility service used for dairy operations of the cattle farm operation.

[0039] Furthermore, in some embodiments, the plurality of instructions may further cause the server computer to receive, for the reference time period of the cattle farm operation, herd demographics data indicative of the population and breed of the cattle herd. In such embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable

greenhouse gas emissions with (i) the feed ingredient usage data, (ii) the utility usage data, and (iii) the herd demographics data as inputs to the model. In such embodiments, to receive the herd demographics data may include to receive sales data indicative of a number of cattle sold from the cattle herd.

[0040] Additionally, in some embodiments, the plurality of instructions may further cause the server computer to receive, for the reference time period of the cattle farm operation, milk production data that identifies an amount of milk type produced by each lactating cattle type of the cattle herd. In such embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable greenhouse gas emissions with (i) the feed ingredient usage data, (ii) the utility usage data, (iii) the herd demographics data, and (iv) the milk production data as inputs to the model.

[0041] In some embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation and to determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to feed cultivation.

[0042] Additionally, in some embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd and determining, by the server computer and for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd.

[0043] In some embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to manure management of the cattle farm operation and to determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions

for the cattle farm operation based on the estimated amount of greenhouse gas emission due to manure management of the cattle farm operation.

[0044] Additionally, in some embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation and to determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation.

[0045] Furthermore, in some embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation; to determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd; to determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to manure management of the cattle farm operation; to determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation; and to determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on (i) the estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation, (ii) the estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd, (iii) the estimated amount of greenhouse gas emission due to manure management of the cattle farm operation, and (iv) the estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation.

[0046] Additionally, in some embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may include to allocate the estimated total amount of controllable greenhouse gas emissions between milk production operations of the cattle farm operation and meat production operations of the cattle farm operation. In such embodiments, to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation may further include to allocate utility usage indicative of an amount of utility service used by the cattle farm operation based on cattle type of the cattle herd.

[0047] In some embodiments, to request the carbon credit may include to determine a reduction of greenhouse gas emissions based on the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation and a baseline greenhouse gas emissions amount. In such embodiments, the plurality of instructions may further cause the server computer to request, for the reference time period of the cattle farm operation, the carbon credit based on the determined reduction of greenhouse gas emissions.

[0048] Additionally, in some embodiments, the plurality of instructions may further cause the server computer to generate greenhouse gas emissions metrics based on the estimated total amount of controllable greenhouse gas emissions and displaying the greenhouse gas emissions metrics to a user. In such embodiments, the greenhouse gas emissions metrics may include indicia of a comparison of the estimated total amount of controllable greenhouse gas emissions for the reference time period and a prior time period. Additionally, in such embodiments, the estimated total amount of controllable greenhouse gas emissions may include a plurality of greenhouse gas emission types and the greenhouse gas emissions metrics may identify an amount of each greenhouse gas emission type. Furthermore, in some embodiments, the plurality of instructions may further cause the server computer to determine a recommended greenhouse gas emission remediation action for the cattle farm operation based on the estimated total amount of controllable greenhouse gas emissions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0049] The concepts described herein are illustrated by way of example and not by way of limitation in the accompanying figures. For simplicity and clarity of illustration, elements illustrated in the figures are not necessarily drawn to scale. Where considered appropriate, reference labels have been repeated among the figures to indicate corresponding or analogous elements.

[0050] FIG. 1 is a simplified block diagram of at least one embodiment of a system for managing a carbon footprint of a cattle farm operation;

[0051] FIG. 2 is a simplified mathematical model for the determination of a greenhouse gas emissions reduction of a cattle farm operation that may be utilized by a server computer of the system of FIG. 1 using a total controllable greenhouse gas emissions model;

[0052] FIG. 3 is a simplified block diagram of an illustrative environment that may be established by the server computer of the system of FIG. 1;

[0053] FIG. 4 is a simplified block diagram of an illustrative environment that may be established by a user computer device of the system of FIG. 1;

[0054] FIGS. 5A-5C are a simplified flow diagram of a method for managing a carbon footprint of a cattle farm operation that may be executed by the server computer of the system of FIG. 1;

[0055] FIG. 6 is a simplified illustration of a user interface that may be displayed on the user computer device by the server computer of the system of FIG 1 during the execution of the method of FIGS. 5A-5C;

[0056] FIG. 7 is a simplified illustration of another user interface that may be displayed on the user computer device by the server computer of the system of FIG 1 during the execution of the method of FIGS. 5A-5C;

[0057] FIG. 8 is a simplified illustration of another user interface that may be displayed on the user computer device by the server computer of the system of FIG 1 during the execution of the method of FIGS. 5A-5C;

[0058] FIG. 9 is a simplified illustration of another user interface that may be displayed on the user computer device by the server computer of the system of FIG 1 during the execution of the method of FIGS. 5A-5C;

[0059] FIG. 10 is a simplified illustration of another user interface that may be displayed on the user computer device by the server computer of the system of FIG 1 during the execution of the method of FIGS. 5A-5C;

[0060] FIG. 11 is a simplified illustration of another user interface that may be displayed on the user computer device by the server computer of the system of FIG 1 during the execution of the method of FIGS. 5A-5C;

[0061] FIGS. 12-14 are a simplified illustrations of portions of a user interface that may be displayed on the user computer device by the server computer of the system of FIG 1 during the execution of the method of FIGS. 5A-5C;

[0062] FIG. 15 is a simplified illustration of another user interface that may be displayed on the user computer device by the server computer of the system of FIG 1 during the execution of the method of FIGS. 5A-5C;

[0063] FIG. 16 is a simplified illustration of another user interface that may be displayed on the user computer device by the server computer of the system of FIG 1 during the execution of the method of FIGS. 5A-5C;

[0064] FIG. 17 is a simplified illustration of another user interface that may be displayed on the user computer device by the server computer of the system of FIG 1 during the execution of the method of FIGS. 5A-5C;

[0065] FIG. 18 is a simplified illustration of another user interface that may be displayed on the user computer device by the server computer of the system of FIG 1 during the execution of the method of FIGS. 5A-5C;

[0066] FIG. 19 is a simplified illustration of greenhouse gas emissions metric that may be displayed on the user computer device by the server computer of the system of FIG 1 during the execution of the method of FIGS. 5A-5C;

[0067] FIG. 20 is a simplified illustration of another greenhouse gas emissions metric that may be displayed on the user computer device by the server computer of the system of FIG 1 during the execution of the method of FIGS. 5A-5C;

[0068] FIG. 21 is a simplified illustration of another greenhouse gas emissions metric illustrating various greenhouse gas emission types that may be displayed on the user computer device by the server computer of the system of FIG 1 during the execution of the method of FIGS. 5A-5C;

[0069] FIG. 22 is a table of animal types considered in the method of FIGS. 5A-5C;

[0070] FIG. 23 is a table of system boundaries of an illustrative cattle farm operation including inputs, outputs, and greenhouse gas emissions;

[0071] FIG. 24 is a table of possible emissions of an illustrative cattle farm operation;

[0072] FIG. 25 is a table of emission factor for a sample list of feed ingredients; and

[0073] FIG. 26 is a table of emission factor for various sources of fuel.

DETAILED DESCRIPTION OF THE DRAWINGS

[0074] While the concepts of the present disclosure are susceptible to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the drawings and will be described herein in detail. It should be understood, however, that there is no intent to limit the concepts of the present disclosure to the particular forms disclosed, but on the contrary, the intention is to cover all modifications, equivalents, and alternatives consistent with the present disclosure and the appended claims.

[0075] References in the specification to “one embodiment,” “an embodiment,” “an illustrative embodiment,” etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may or may not necessarily include

that particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to effect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described. Additionally, it should be appreciated that items included in a list in the form of “at least one A, B, and C” can mean (A); (B); (C); (A and B); (B and C); or (A, B, and C). Similarly, items listed in the form of “at least one of A, B, or C” can mean (A); (B); (C); (A and B); (B and C); or (A, B, and C).

[0076] The disclosed embodiments may be implemented, in some cases, in hardware, firmware, software, or any combination thereof. The disclosed embodiments may also be implemented as instructions carried by or stored on a transitory or non-transitory machine-readable (e.g., computer-readable) storage medium, which may be read and executed by one or more processors. A machine-readable storage medium may be embodied as any storage device, mechanism, or other physical structure for storing or transmitting information in a form readable by a machine (e.g., a volatile or non-volatile memory, a media disc, or other media device).

[0077] In the drawings, some structural or method features may be shown in specific arrangements and/or orderings. However, it should be appreciated that such specific arrangements and/or orderings may not be required. Rather, in some embodiments, such features may be arranged in a different manner and/or order than shown in the illustrative figures. Additionally, the inclusion of a structural or method feature in a particular figure is not meant to imply that such feature is required in all embodiments and, in some embodiments, may not be included or may be combined with other features.

[0078] The preset disclosure provides technologies for monitoring and managing greenhouse gas emissions (e.g., carbon dioxide, nitrous oxide, and methane) in a cattle farm operation so as to determine a carbon footprint of that cattle farm operation. In particular, the disclosed technologies monitor and determine reduction in greenhouse gas emissions due to the administration of feed additives, monensin and/or 3-nitrooxypropanol, to the diet of the cattle herd of the cattle farm operation. The reduction of greenhouse gas emissions may be documented to as to receive carbon credits based on such reduction. Generally, a carbon credit refers to a mechanism to compensate for emissions of carbon dioxide or other greenhouse gases. For instance, one carbon credit can represent an emission reduction or removal of one metric ton of carbon dioxide or the equivalent amount of greenhouse gases. A carbon credit can also be referred to as a carbon offset.

[0079] Monensin (also known as Rumensin™) is a feed additive approved by the U.S. Food and Drug Administration Center for Veterinary Medicine for improved milk production efficiency, defined as production of marketable solids-corrected milk per unit of feed intake corrected for changes in body weight. For instance, in growing cattle (including replacement heifers), monensin increases the rate of weight gain and also prevents and controls coccidiosis. Monensin improves milk production efficiency in dairy cows by shifting rumen bacterial populations to produce more propionate which is a more efficient use of feedstuffs because there is a reduction in the amount of energy spent as carbon dioxide and methane. Figure 1 summarizes adjustments utilized to quantify the effect of monensin on greenhouse gas emissions.

[0080] Monensin use in lactating dairy cattle can significantly decrease dry matter intake (DMI) by, for example, 2.3% and increased milk yield by 2.3%. As significant heterogeneity has been observed with milk components, the reported yield and component percentages can be used to calculate solids-corrected milk (SCM) differences between control and monensin treatments according to NRC 2001, resulting in a 0.5% increase in SCM with monensin. Therefore, a conservative positive increase of 0.5% can be utilized for the monensin effect on both SCM and milk yield. For dry cows, monensin trials have demonstrated a 2.7% dry matter intake reduction.

[0081] The mode of action of monensin for milk production efficiency results in reduced methane production. The impacts of feeding monensin to cattle include both a direct reduction in CH₄ emissions from enteric fermentation and an indirect reduction in enteric fermentation emissions through decreased DMI with no negative effects on health and a positive benefit to milk production. The persistent benefit of feeding cattle Rumensin is supported by multiple scientific studies that have measured reductions in CH₄ emissions from enteric fermentation. Due to the effect of monensin on decreased DMI, the greenhouse gas impact of feed cultivation and manure is also reduced, providing an additional greenhouse gas benefit. These impacts are credited through the process and calculations in this protocol.

[0082] Monensin reduces absolute emissions in the production of a consumer good along the value chain. Enteric methane is generated through the fermentation of feed an animal consumes at regular intervals throughout the day. Since monensin acts by reducing enteric methane and feed intake, the reductions in greenhouse gas emissions associated with feeding monensin are permanent and cannot be reversed. Each day monensin is not fed to an animal, 3-5% more enteric methane is released into the environment.

[0083] Moreover, a body of peer-reviewed literature shows 3-nitrooxypropanol (also known as 3-NOP or Bovaer™) reduces enteric methane emissions approximately 30% or 1 metric

ton (MT) of CO₂, depending on dose and diet which can be modeled to provide a more accurate reduction estimate. Assuming the enteric methane output of a dairy cow averages 4 MT of carbon dioxide equivalents (CO₂e) per year, 3-NOP has the potential to permanently avoid 0.8 to 1.6 MT CO₂e per cow per year. If 3-NOP were implemented in 50% of the 7.9 million lactating cows in the U.S. (USDA-NASS, 2023), between 3.1 and 6.3 MMT of CO₂e would be permanently avoided annually.

[0084] Without being bound by any theory, 3-NOP has a mode of action works through targeted oxidation of nickel in methyl-coenzyme M reductase (MCR), leading to its inhibition in the final step of methane formation. After exerting its action, 3-NOP is converted to substances naturally produced in rumen fermentation. The impact of 3-NOP on methane reduction and productivity has been evaluated and its effect on methane reduction is approximately 30% or 1 MT of CO₂, depending on dose and diet which can be modeled to provide a more accurate reduction estimate. 3-NOP reduces enteric methane and thus absolute emissions in the production of a consumer good along the entire value chain. Each day 3-NOP is not fed to an animal, approximately 30% or 1 MT more enteric methane is released into the environment compared to what would be emitted if 3-NOP were being fed. Emissions reductions associated with feeding 3-NOP are permanent and cannot be reversed.

[0085] As discussed above, the disclosed technologies facilitate the determination of a carbon footprint of a cattle farm operation, the evaluation of mitigation strategies including feed additives, and the verification of reductions of greenhouse gas emissions in the cattle farm operation due to such mitigation efforts. To do so, the disclosed technologies utilize a total controllable greenhouse gas emissions model to determine the carbon footprint of the cattle farm operation using a life cycle analysis approach.

[0086] A typical cattle farm operation may be embodied as a dairy farm, which focuses primarily on milk production, with beef and crop production as secondary outputs. The cattle of the cattle farm may be located on a single site or across multiple sites. The cattle herd may include one or more different types of cattle, as shown in table 2200 of FIG. 22. In the illustrative embodiment, the cattle herd may include lactating cows, dry cows, replacement heifers of 0-12 months, replacement heifers of 12+ months, and/or beef animals. Additionally, as shown in system 2300 of FIG. 23, a typical cattle farm operation includes a number of primary inputs and outputs, with the byproduct of generated greenhouse gas. For example, the primary inputs may include feed ingredients, fuel, and/or utilities (e.g., electricity), and the primary outputs may include milk production and meat production. The various cattle types, as well as the manure

handling of those cattle types, produces an amount of greenhouse gas, which may include carbon dioxide, nitrous oxide, and/or methane.

[0087] The technologies disclosed herein consider several sources, sinks, and/or reservations (SSRs) in determining the total greenhouse gas emissions of an illustrative cattle farm operation, while excluding others for various reasons. For example, in an illustrative embodiment, the disclosure technologies may include a system boundary as identified in table 2400 of FIG. 24. In the illustrative embodiment, greenhouse gas emissions from feed cultivation sources, enteric fermentation sources, manure management sources, and fuel and electricity use sources are considered, while direct land use sources, bedding sources, and waste processing sources are not. In other embodiments, additional or different sources of greenhouse gas emissions may be considered.

[0088] Referring now to FIG. 1, a system 100 for managing a carbon footprint of a cattle farm operation includes a greenhouse gas (GHG) monitoring server 102 and at least one user computer device 104, which are configured to communicate with each other over a network 106. In use, as discussed in more detail below, a user of the user computer device 104 may provide operation data related to the cattle farm operation to the GHG monitoring server 102, which is configured to determine an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using a model of total controllable greenhouse gas emissions with the operation data as input to that model. The operation data includes feed ingredient usage data for the cattle herd, including the identified of one or more feed additives (e.g., monensin and 3-nitrooxypropanol) included in the feed. As discussed above, the feed additives are operable to reduce an amount of greenhouse gas emission produced by the feeding cattle. The GHG monitoring server 102 may also request a carbon credit based on the estimated total amount of controllable greenhouse gas emissions, which may be defined as a reduction of greenhouse gas emission relative to a baseline or prior time period.

[0089] In some embodiments, the operation data of the related to the cattle farm operation may include additional input data, such as utility usage data and/or herd demographics and milk productivity data. The GHG monitoring server 102 utilizes each of those operation data as inputs to a mathematical model of total controllable GHG emissions. To do so and as discussed above, the mathematical model maintained by the GHG monitoring server 102 determines total greenhouse gas emissions from various sources using a feed cultivation sub-model, an enteric fermentation sub-model, a manure management sub-model, and a utility usage sub-model using one or more of the feed ingredient usage, the utility usage, and/or the demographics and

productivity data as input to their individual models. The GHG monitoring server 102 combines the outputs of those sub-models to determine the total controllable greenhouse gas emissions of the cattle farm operation. In some embodiments, the GHG monitoring server 102 may be configured to allocate portions of the total controllable greenhouse gas emissions of the cattle farm operation to the milk production and/or meat production of the cattle farm operation. Additionally, the GHG monitoring server 102 is configured to compare that determined total controllable greenhouse gas emissions of the cattle farm operation to a baseline amount of greenhouse gas emissions, which may be based on prior measurements or a default level, to determine an overall reduction of greenhouse gas emissions for the cattle farm operation, which may be due to the addition of the feed additives. As such and as discussed above, the GHG monitoring server 102 may request carbon credits for the determined reduction in total greenhouse gas emissions of the cattle farm operation (i.e., a reeducation in the carbon footprint of the cattle farm operation). Furthermore, the GHG monitoring server 102 may be configured to provide GHG metrics to the user of the user computer device, which may be useful in monitoring the overall production of greenhouse gas emissions as well as the ongoing reduction of those greenhouse gas emissions. The GHG monitoring server 102 may also identify possible remediation recommendations that the operation of the cattle farm operation may perform to further reduce the total greenhouse gas emissions of that cattle farm operation.

[0090] The GHG monitoring server 102 may be embodied as any type of computation or computer device capable of performing the functions described herein, including, without limitation, a server, a rack-mounted server, a blade server, a workstation, a network appliance, a web appliance, a desktop computer, a laptop computer, a tablet computer, a smartphone, a consumer electronic device, a distributed computing system, and/or a multiprocessor system. Additionally, in some embodiments, the GHG monitoring server 102 may be embodied as a “virtual server” formed from multiple computing devices distributed across the network 106 and operating in a public or private cloud. Accordingly, although the GHG monitoring server 102 is illustrated in FIG. 1 as embodied as a single computing device, it should be appreciated that the GHG monitoring server 102 may be embodied as multiple devices cooperating together to facilitate the functionality described below.

[0091] As shown in FIG. 1, the illustrative GHG monitoring server 102 includes compute circuitry 120, an I/O subsystem 126, a data storage device 128, and a communication subsystem 130. Of course, the GHG monitoring server 102 may include other or additional components, such as those commonly found in a typical server or other computer (e.g., various input/output

devices), in other embodiments. Additionally, in some embodiments, one or more of the illustrative components may be incorporated in, or otherwise form a portion of, another component.

[0092] The compute circuitry 120 may be embodied as any type of device or collection of devices capable of performing various compute functions. In some embodiments, the compute circuitry 120 may be embodied as a single device such as an integrated circuit, an embedded system, a field-programmable-array (FPGA), a system-on-a-chip (SOC), or other integrated system or device. Additionally, in some embodiments, the compute circuitry 120 includes or is embodied as a processor 122 and memory 124. The processor 122 may be embodied as any type of processor capable of performing the functions described herein. For example, the processor 122 may be embodied as a single or multi-core processor(s), digital signal processor, microcontroller, or other processor or processing/controlling circuit. Similarly, the memory 124 may be embodied as any type of volatile or non-volatile memory or data storage capable of performing the functions described herein. In operation, the memory 124 may store various data and software used during operation of the GHG monitoring server 102 such as operating systems, applications, programs, libraries, and drivers.

[0093] The compute circuitry 120 is communicatively coupled to other components of the GHG monitoring server 102 via the I/O subsystem 126, which may be embodied as circuitry and/or components to facilitate input/output operations with compute circuitry 120 (e.g., with the processor 122 and/or memory 124) and other components of the GHG monitoring server 102. For example, the I/O subsystem 126 may be embodied as, or otherwise include, memory controller hubs, input/output control hubs, firmware devices, communication links (i.e., point-to-point links, bus links, wires, cables, light guides, printed circuit board traces, etc.) and/or other components and subsystems to facilitate the input/output operations. In some embodiments, the I/O subsystem 126 may be incorporated, along with the processor 122, the memory 124, and other components of the GHG monitoring server 102, into the compute circuitry 120.

[0094] The data storage device 128 may be embodied as any type of device or devices configured for short-term or long-term storage of data such as, for example, memory devices and circuits, memory cards, hard disk drives, solid-state drives, or other data storage devices. The communication subsystem 130 of the GHG monitoring server 102 may be embodied as any communication circuit, device, or collection thereof, capable of enabling communications between the GHG monitoring server 102 and the user computer device 104 over the network 106. The communication subsystem 130 may be configured to use any one or more communication

technology (e.g., wireless or wired communications) and associated protocols (e.g., Ethernet, Bluetooth®, Bluetooth Low Energy (BLE), Wi-Fi®, WiMAX, 3G LTE, 5G, etc.) to effect such communication.

[0095] The user computer device 104 may be embodied as any type of computer device capable of performing the functions described herein. For example, the user computer device 104 may be embodied as, without limitation, a smartphone, a mobile computing device, a computer, a laptop computer, a notebook computer, a tablet computer, a wearable computing device, a processor-based system, and/or a consumer electronic device. In the illustrative embodiment, each user computer device 104 is embodied as a personal computer device on which the respective user may maintain a personal digital calendar, in some embodiments. The personal digital calendar may be stored locally on the user computer device 104 or on another computer device (e.g., the GHG monitoring server 102 or a third-party server) of the system 100.

[0096] As shown in FIG. 1 and similar to the GHG monitoring server 102, the user computer device 104 includes compute circuitry 150, an I/O subsystem 156, an output device 158, and a communication subsystem 160. Of course, the user computer device 104 may include other or additional components, such as those commonly found in a mobile computer device (e.g., short and/or long term data storage), in other embodiments. Additionally, in some embodiments, one or more of the illustrative components may be incorporated in, or otherwise form a portion of, another component.

[0097] The compute circuitry 150 may be embodied as any type of device or collection of devices capable of performing various compute functions. In some embodiments, the compute circuitry 150 may be embodied as a single device such as an integrated circuit, an embedded system, a field-programmable-array (FPGA), a system-on-a-chip (SOC), or other integrated system or device. Additionally, in some embodiments, the compute circuitry 150 includes or is embodied as a processor 152 and memory 154. The processor 152 may be embodied as any type of processor capable of performing the functions described herein. For example, the processor 152 may be embodied as a single or multi-core processor(s), digital signal processor, microcontroller, or other processor or processing/controlling circuit. Similarly, the memory 154 may be embodied as any type of volatile or non-volatile memory or data storage capable of performing the functions described herein. In operation, the memory 154 may store various data and software used during operation of the user computer device 104 such as operating systems, applications, programs, libraries, and drivers.

[0098] The compute circuitry 150 is communicatively coupled to other components of the user computer device 104 via the I/O subsystem 156, which may be embodied as circuitry and/or components to facilitate input/output operations with compute circuitry 150 (e.g., with the processor 152 and/or memory 154) and other components of the respective user computer device 104. For example, the I/O subsystem 156 may be embodied as, or otherwise include, memory controller hubs, input/output control hubs, firmware devices, communication links (i.e., point-to-point links, bus links, wires, cables, light guides, printed circuit board traces, etc.) and/or other components and subsystems to facilitate the input/output operations. In some embodiments, the I/O subsystem 156 may be incorporated, along with the processor 152, the memory 154, and other components of the respective user computer device 104, into the compute circuitry 150.

[0099] The output device(s) 158 may be embodied as any type of output device capable of presenting an output or information to the user of the respective user computer device 104. For example, in the illustrative embodiment, the output device 158 is embodied as, or otherwise include, a visual output device such as a display screen.

[00100] The communication subsystem 160 of the user computer device 104 may be embodied as any communication circuit, device, or collection thereof, capable of enabling communications between the user computer device 104, the GHG monitoring server 102, and/or other computer devices of the system 100. The communication subsystem 160 may be configured to use any one or more communication technology (e.g., wireless or wired communications) and associated protocols (e.g., Ethernet, Bluetooth®, Bluetooth Low Energy (BLE), Wi-Fi®, WiMAX, 3G LTE, 5G, etc.) to effect such communication.

[00101] As discussed in more detail below, the GHG monitoring server 102 is configured to communicate with the user computer device and/or other devices of the system 100 over the network 106. The network 106 may be embodied as any number of various wired and/or wireless networks. For example, the network 106 may be embodied as, or otherwise include, a wired or wireless local area network (LAN), a wired or wireless wide area network (WAN), a cellular network, and/or a publicly-accessible, global network such as the Internet. As such, the network 106 may include any number of additional devices, such as additional computers, routers, stations, and switches, to facilitate communications among the devices of the system 100.

[00102] In some embodiments, the system 100 may also include a herd management system 110, a feed management system 112, and/or a utility management system 114, each of which may communicate with the GHG monitoring server 102 over a local network 116 (e.g., a local area network) and/or the network 106. The herd management system 110 may be embodied

as any hardware and/or software component configured to provide management services for the cattle herd of the cattle farm operation (e.g., maintain or determine the count of each cattle type of the cattle herd). Similarly, the feed management system 112 may be embodied as any hardware and/or software component configured to provide management services for the feed provided to the cattle herd of the cattle farm operation (e.g., maintain or determine the total amount of each ingredient of the feed per cattle type). Additionally, the utility management system 114 may be embodied as any hardware and/or software component configured to provide management services for the utility usage of the cattle farm operation (e.g., maintain or determine the utility usage for each cattle type). Additionally, in some embodiments, the system 100 may further include one or more sensors 118 which may be employed by one or more of the management systems 110, 112, 114 in determining the providing the related management services. For example, the sensors 118 may include cattle sensor configured to generate sensor data indicative of a count of each cattle as the cattle moves from one monitoring station to another or feed sensors configured to generate sensor data indicative of the total amount feed provided to different cattle type.

[00103] Referring now to FIG. 2, as discussed above, the GHG monitoring server 102 is configured to utilize a total controllable greenhouse gas emissions mathematical model 200 to determine the total greenhouse gas emissions (and/or reduction thereof) of the respective cattle farm operation. As shown, the mathematical model 200 includes several inputs including feed ingredient usage input 202, utility usage input 204, and herd demographics and productivity usage 206. As discussed in more detail below, the feed ingredient usage input 202 defines the amount of feed provided to each cattle type for the reference/reporting period and includes the identification of any feed additive ((e.g., monensin and 3-nitrooxypropanol)) included in the feed. The utility usage input 204 defines the amount utility service (e.g., fuel and/or electricity) used by the cattle farm operation for the reference/reporting period. Additionally, the herd demographics and productivity usage 206 defines the population and breed of the cattle herd and the amount of milk type produced by each lactating cattle type of the cattle herd.

[00104] As discussed above, the mathematical model 200 includes several sub-models including for determining the total controllable greenhouse gas emissions of the cattle farm operation. That is, a sub-model is included for each of the included sources identified in table 2400 of FIG. 4. In the illustrative embodiment the mathematical model 200 includes a greenhouse gas emissions from feed cultivation sub-model 210, a greenhouse gas emissions from

enteric fermentation sub-model 212, a greenhouse gas emissions from manure management sub-model 214, and a greenhouse gas emissions from utility usage sub-model 216.

[00105] Feed Cultivation

[00106] The feed cultivation sub-model 210 is a mathematical model configured to determine an amount of greenhouse gas emissions of the cattle farm operation produced during the reference/reporting period from the feed cultivation activities. To do so, in the illustrative embodiment, the total greenhouse gas emissions from the cultivation of feed fed to the cattle herd during the reference/reporting period is determined based on the following Equation (1):

$$[00107] \quad GHG_{feed,P} = \sum_T GHG_{feed_T}^{TOTAL,P} + MR \quad (1)$$

[00108] wherein $GHG_{feed,P}$ is the GHG emissions from the cultivation of feed fed during the reporting period (kg CO₂e), $GHG_{feed_T}^{TOTAL,P}$ is the total feed greenhouse gas emissions for cattle type T during the reporting period (kg), and MR is the GHG emissions from the production of milk replacer fed during the reporting period which is determined by Equation (4) for heifers <12 months of age, this value is 0 for all other cattle types (kg CO₂e).

[00109] The total feed greenhouse gas emissions for cattle type, $GHG_{feed_T}^{TOTAL,P}$, is determined based on the following Equation (2):

$$[00110] \quad GHG_{feed_T}^{TOTAL,P} = \sum_i (DMI_P^T \times C^T \times EF_{diet_T} \times t) \quad (2)$$

[00111] wherein $GHG_{feed_T}^{TOTAL,P}$ is the total feed greenhouse gas emissions for cattle type T during the reporting period (kg), DMI_P^T is the average daily dry matter intake for cattle type T during the reporting period (kg DM per head per day), C^T is the number of cattle type T fed during the reporting period (head), EF_{diet_T} is the emissions factor of the total diet fed to cattle type T during the reporting period (kg CO₂e per kg DM), and t is the number of days in the reporting period (days). EF_{diet_T} is calculated according to Equation (3).

[00112] The emissions factor, EF_{diet_T} , of the diet fed to cattle type T during the reporting period is determined based on the following Equation (3):

$$[00113] \quad EF_{diet_T} = \sum_i EF_{feed_i} \times \varphi_{feed_i}^T \quad (3)$$

[00114] wherein EF_{diet_T} is the emissions factor of the total diet fed to cattle type T during the reporting period (kg CO₂e per kg DM), EF_{feed_i} is the emissions factor (kg CO₂e per kg DM) for feed I, and $\varphi_{feed_i}^T$ is the fractional makeup of feed i for cattle type T (i.e., the percent of the diet that is feed i on a DM basis).

[00115] Additionally, the GHG emissions, MR , from the production of milk replacer fed during the reporting period, which is used in the determination of the total greenhouse gas emissions from the cultivation of feed fed to the cattle herd during the reference/reporting period in Equation (1), is determined based on the following Equation (4):

$$[00116] \quad MR = MRI \times MREF \times PWHfr \times t \quad (4)$$

[00117] where MR is the GHG emissions from the production of milk replacer fed during the reporting period (kg CO₂e), MRI is the milk replacer intake (kg DM per head per day), $MREF$ is the milk replacer emissions factor; 12.1 from Rotz et al., 2021 (kg CO₂e per kg DM), $PWHfr$ is the number of pre-weaned replacement heifers fed during the reporting period (head) (19.3% of the replacement heifers 0 to 12 months of age), and t is the number of days in the reporting period (days).

[00118] Furthermore, the milk replacer intake, MRI , is determine based on the following Equation (5):

$$[00119] \quad MRI = \left(\frac{8.6}{4 \times 2.20462} \right) \times LFV \times MRP \times MRDM \quad (5)$$

[00120] wherein MRI is the milk replacer intake (kg DM per head per day), 8.6 is the conversion factor (pounds per gallon), 4 is the conversion factor (quarts per gallon), 2.20462 is the conversion factor (pounds per kilogram), LFV is the liquid feed volume fed (quarts per day), MRP is the proportion of liquid feed that is milk replacer (%), and $MRDM$ is the dry matter content of milk replacer (13.0 from NASEM, 2021). A list emission factors, including dry matter content, for sample feed ingredients is shown in table 25 of FIG. 25.

[00121] Enteric Fermentation

[00122] The enteric fermentation sub-model 212 is a mathematical model configured to determine an amount of greenhouse gas emissions of the cattle farm operation produced during the reference/reporting period from the enteric fermentation of the respective cattle herd. To do so, in the illustrative embodiment, the total greenhouse gas emissions from the enteric fermentation of the cattle herd during the reference/reporting period is determined based on the following Equation (6):

$$[00123] \quad GHG_{ent,P}^T = \sum_T (CH_4^T_{ent,P} \times GWP_{CH_4}) \quad (6)$$

[00124] wherein $GHG_{ent,P}^T$ is the GHG emissions from enteric fermentation from cattle type T during the reporting period (kg CO₂e), $CH_4^T_{ent,P}$ is the methane emissions from enteric fermentation for cattle type T during the reporting period (kg CH₄), and GWP_{CH_4} is 27 (global warming potential of methane (tCO₂e per tCH₄; IPCC, 2021)).

[00125] The methane emission from enteric fermentation for cattle type T during the reporting period, $CH_4^{T}_{ent,P}$, is determined based on the following Equation (7):

$$[00126] \quad CH_4^{T}_{ent,P} = EF_{CH_4\ ent,P}^T \times C^T \times t \quad (7)$$

[00127] where $CH_4^{T}_{ent,P}$ is the methane emissions from enteric fermentation for cattle type T during the reporting period (kg CH₄), $EF_{CH_4\ ent,P}^T$ is the emission factor for methane of cattle type T during the reporting period (kg CH₄ per head per day), C^T is the number of cattle type T fed during the reporting period (head), and t is the number of days in the reporting period (days).

[00128] The emission factor for methane of cattle type T during the reporting period, $EF_{CH_4\ ent,P}^T$, is determine based on the following Equation (8):

$$[00129] \quad EF_{CH_4\ ent,P}^T = \frac{DMI_P^T \times GE_T \times \left(\frac{Y_{m,P}^T}{100}\right)}{55.65} \quad (8)$$

[00130] where $EF_{CH_4\ ent,P}^T$ is the emission factor for methane of cattle type T during the reporting period (kg CH₄ per head per day), DMI_P^T is the average daily dry matter intake for cattle type T during the reporting period (kg DM per head per day), $Y_{m,P}^T$ is the methane conversion factor of cattle type T during the reporting period (percentage of dietary gross energy lost as CH₄), 55.65 is the energy content of methane (MJ per kg CH₄), and GE_T is the gross energy concentration of diet for cattle type T (MJ per kg dry matter).

[00131] Manure Management

[00132] The manure management sub-model 214 is a mathematical model configured to determine an amount of greenhouse gas emissions of the cattle farm operation produced during the reference/reporting period from the manure management operations for the cattle herd. To do so, in the illustrative embodiment, the total greenhouse gas emissions from the manure management for the reference/reporting period is determined based on the following Equations (9), (10), (11):

$$[00133] \quad GHG_{man,P} = \sum_T (GHG_{manCH_4,P}^T \times GHG_{manN_2O,P}^T) \quad (9)$$

$$[00134] \quad GHG_{manCH_4,P}^T = CH_4^T_{man,P} \times GWP_{CH_4} \quad (10)$$

$$[00135] \quad GHG_{manN_2O,P}^T = N_2O^T_{man,P} \times GWP_{N_2O} \quad (11)$$

[00136] wherein $GHG_{man,P}$ is the total GHG emissions from manure management for during the reporting period (kg CO₂e), $GHG_{manCH_4,P}^T$ is the GHG emissions from manure methane for cattle type T during the reporting period (kg CO₂e), $GHG_{manN_2O,P}^T$ is the GHG emissions from manure nitrous oxide for cattle type T during the reporting period (kg CO₂e), $CH_4^T_{man,P}$ is the methane emissions from manure production for cattle type T during the reporting period (kg

CH₄), GWP_{CH_4} is 27 (global warming potential of methane (kg CO₂e per kg CH₄), $N_2O_{man,P}^T$ is the nitrous oxide emissions from manure production for cattle type T during the reporting period (kg N₂O), and GWP_{N_2O} is 273 (global warming potential of nitrous oxide (kg CO₂e per kg N₂O; IPCC, 2021)).

[00137] The methane emissions from manure production for cattle type T during the reporting period, $CH_4^T_{man,P}$, is determined from the following Equation (12):

$$[00138] \quad CH_4^T_{man,P} = \sum_{S,T} (MS_{S,P}^T) \quad (12)$$

[00139] where $CH_4^T_{man,P}$ is the methane emissions from manure production for cattle type T during the reporting period (kg CH₄) and $MS_{S,P}^T$ is the methane emissions from storage/treatment system S by cattle type T, aggregated for the reporting period (kg CH₄).

[00140] The methane emissions from storage/treatment system S by cattle type T, $MS_{S,P}^T$, is determined from the following Equation (13):

$$[00141] \quad MS_{S,P}^T = (C^T \times PS_{S,P}^T \times VS_P^T \times MCF_S \times B_0^T \times \rho_{CH_4} \times t) \quad (13)$$

[00142] where $MS_{S,P}^T$ is the methane emissions from storage/treatment system S by cattle type T, aggregated for the reporting period (kg CH₄), C^T is the number of cattle type T fed during the reporting period (head), $PS_{S,P}^T$ is the percent of manure sent to (managed in) manure storage/treatment system S from cattle type T in the reporting period (%), VS_P^T is the volatile solids produced by cattle type T on a dry matter basis during the reporting period (kg per head per day), MCF_S is the methane conversion factor for storage/treatment system S (IPCC, 2019a Table 10.17; %), B_0^T is the maximum methane-producing capacity of manure for cattle type T (IPCC, 2019a Table 10.16; m³ CH₄ per kg VS), ρ_{CH_4} is 0.67 (density of methane = 0.67 at 1 atm and 60°F (kg per m³)), and t is the number of days in the reporting period (days).

[00143] The volatile solids produced by cattle type T on a dry matter basis during the reporting period, VS_P^T , is determined from the following Equations (14) and (15) (simplified):

$$[00144] \quad VS_P^T = \left[(DMI_P^T \times GE_P^T) \times \left(1 - \frac{DE_P^T}{100} \right) + (UE \times [DMI_P^T \times GE_P^T]) \right] \times \left[\frac{1-ASH}{GE_P^T} \right] \quad (14)$$

$$[00145] \quad VS_P^T = DMI_P^T \times \left(\left(1 - \frac{DE_P^T}{100} \right) + UE \right) \times (1 - ASH) \quad (15)$$

[00146] wherein VS_P^T is the volatile solids produced by cattle type T on a dry matter basis during the reporting period (kg per head per day), DMI_P^T is the average daily dry matter intake for cattle type T during the reporting period (kg DM per head per day), GE_P^T is the gross energy concentration of diet for cattle type T during the reporting period (MJ per kg dry matter), DE_P^T is

the average diet digestibility of the feed for cattle type T in the reporting period (% of gross energy), UE is 4% (urinary energy as a percent of gross energy in the reporting period (IPCC, 2019a Equation 10.24; %)), and ASH is 8% (ash content of feed in the reporting period (Dämmgen et al., 2011; %)).

[00147] The nitrous oxide emissions from manure production for cattle type T during the reporting period, $N_2O_{man,P}^T$, from Equation (11) is determined from the following Equation (16):

$$[00148] \quad N_2O_{man,P}^T = \sum_T (N_2O_{d,P}^T + N_2O_{i,l,P}^T + N_2O_{i,v,P}^T) \quad (16)$$

[00149] wherein $N_2O_{man,P}^T$ is the nitrous oxide emissions from manure production for cattle type T during the reporting period (kg N₂O), $N_2O_{d,P}^T$ is the direct N₂O emissions from manure management for cattle type T during the reporting period (kg N₂O), $N_2O_{i,l,P}^T$ is the indirect N₂O emissions from leaching of manure for cattle type T during the reporting period (kg N₂O), and $N_2O_{i,v,P}^T$ is the indirect N₂O emissions from the volatilization of NH₃ and NO_x for cattle type T during the reporting period (kg N₂O).

[00150] The direct N₂O emissions from manure management for cattle type T during the reporting period, $N_2O_{d,P}^T$, is determined from the following Equations (17) and (18):

$$[00151] \quad N_2O_{d,P}^T = \left(\sum_S N_{S,P}^T \right) \times EF_{d,S} \times \frac{44}{28} \quad (17)$$

$$[00152] \quad N_{S,P}^T = (N_{ex,P}^T \times PS_{S,P}^T) \quad (18)$$

[00153] wherein $N_2O_{d,P}^T$ is the direct N₂O emissions from manure management for cattle type T during the reporting period (kg N₂O), $N_{S,P}^T$ is the total nitrogen from cattle type T managed by storage system S during the reporting period (kg N), $EF_{d,S}$ is the emissions factor for direct N₂O emissions from the manure management system S in (kg N₂O-N per kg N excreted) (IPCC, 2019a Table 10.21), $\frac{44}{28}$ is the conversion of N₂O-N emissions, to N₂O emissions, $N_{ex,P}^T$ is the N excretion by cattle type T, aggregated for the reporting period (kg N), and $PS_{S,P}^T$ is the percent of manure sent to (managed in) manure storage/treatment system S from cattle type T in the reporting period (%).

[00154] The N excretion by cattle type T, aggregated for the reporting period, $N_{ex,P}^T$, is determined using the following Equation (19):

$$[00155] \quad N_{ex,P}^T = (N_{i,P}^T - N_{R,P}^T) \times C^T \times t \quad (19)$$

[00156] where $N_{ex,P}^T$ is the N excretion by lactating animals, aggregated for the reporting period (kg N), $N_{i,P}^T$ is the nitrogen intake for cattle type T during the reporting period (kg per head per day), $N_{R,P}^T$ is N retained by lactating animals (kg per head per day), C^T is the number of cattle

type T fed during the reporting period (head), and t is the number of days in the reporting period (days).

[00157] The nitrogen intake for cattle type T during the reporting period, $N_{i,p}^T$, is determined using the following Equation (20):

$$[00158] \quad N_{i,p}^T = DMI_P^T \times \frac{CP^T}{6.25} \quad (20)$$

[00159] where $N_{i,p}^T$ is the nitrogen intake for cattle type T during the reporting period (kg per head per day), DMI_P^T is the average daily dry matter intake for cattle type T during the reporting period (kg DM per head per day), CP^T is the crude protein content in the diet for cattle type T (%), and 6.24 is the conversion from kg of dietary protein to kg of dietary N (kg feed protein per kg N).

[00160] The N retained by lactating animals, $N_{R,p}^T$, is determined using the following Equation (21):

$$[00161] \quad N_{R,p}^T = \left[\frac{M \times \left(\frac{M_p}{100} \right)}{6.38} \right] + \left[\frac{WG \times \left[\frac{268 - \left(\frac{7.03 \times NE_G}{WG} \right)}{1000} \right]}{6.25} \right] \quad (21)$$

[00162] where $N_{R,p}^T$ is N retained by lactating animals (kg per head per day), M is the milk production (kg per head per day), M_p is the percent of protein in the milk (%), 6.38 is the conversion from milk protein to milk N (kg protein per kg N), WG is the weight gain (0 for mature lactating cattle), and NE_G is the net energy for growth (MJ/d) (not applicable for lactating mature lactating cattle because weight gain = 0).

[00163] Additionally, the nitrogen excretion for all other cattle types (e.g., dry cows, replacement heifers, and beef) is determined using the following Equation (22):

$$[00164] \quad N_{ex,p}^T = N_{i,p}^T \times (1 - N_{R,frac}^T) \times C^T \times t \quad (22)$$

[00165] where $N_{ex,p}^T$ is the N excretion by cattle type T, aggregated for the reporting period (kg N), $N_{i,p}^T$ is the nitrogen intake for cattle type T during the reporting period (kg per head per day), $N_{R,frac}^T$ is the N retention fraction in non-lactating cattle types f (IPCC, 2019a Table 10A.2; kg N retained per head per day per kg N intake per head per day), C^T is the number of cattle type T fed during the reporting period (head), and t is the number of days in the reporting period (days).

[00166] The indirect N₂O emissions from leaching of manure for cattle type T during the reporting period, $N_2O_{i,l,p}^T$, is determined using the following Equation (23):

[00167]
$$N_2O_{i,l,P}^T = \sum_S (N_{S,P}^T \times \text{Frac}_{\text{leach}_{MS_S}^T}) \times EF_5 \times \frac{44}{28} \quad (23)$$

[00168] where $N_2O_{i,l,P}^T$ is the indirect N₂O emissions from leaching of manure for cattle type T during the reporting period (kg N₂O), $N_{S,P}^T$ is the total nitrogen from cattle type T managed by storage system S during the reporting period (kg N), $\text{Frac}_{\text{leach}_{MS_S}^T}$ is the fraction of managed manure nitrogen losses for cattle type T due to runoff and leaching during solid and liquid storage of manure in manure management system S (IPCC, 2019a Table 10.22), EF_5 is the emission factor for N₂O emissions from nitrogen leaching and runoff from (IPCC, 2019b Table 11.3; kg N₂O-N per kg N leached and runoff), and $\frac{44}{28}$ is the conversion of N₂O-N emissions to N₂O emissions.

[00169] The indirect N₂O emissions from the volatilization of NH₃ and NO_x for cattle type T during the reporting period, $N_2O_{i,v,P}^T$, is determined using the following Equation (24):

[00170]
$$N_2O_{i,v,P}^T = \sum_S (N_{S,P}^T \times \text{Frac}_{\text{Gas}_{MS_S}^T}) \times EF_4 \times \frac{44}{28} \quad (24)$$

[00171] whereing $N_2O_{i,v,P}^T$ is the indirect N₂O emissions from the volatilization of NH₃ and NO_x for cattle type T during the reporting period (kg N₂O), $N_{S,P}^T$ is the total nitrogen from cattle type T managed by storage system S during the reporting period (kg N), $\text{Frac}_{\text{Gas}_{MS_S}^T}$ is the fraction of managed manure nitrogen losses for cattle type T that volatilizes as NH₃ and NO_x in the manure management system S (IPCC, 2019a Table 10.22), 4 is the emission factor for N₂O emissions from nitrogen volatilization (IPCC, 2019b Table 11.3; kg N₂O-N per kg NH₃-N + NO_x-N volatilized), and $\frac{44}{28}$ is the conversion of N₂O-N emissions to N₂O emissions.

[00172] Utility (Fuel & Electricity) Usage

[00173] The utility usage sub-model 216 is a mathematical model configured to determine an amount of greenhouse gas emissions of the cattle farm operation produced during the reference/reporting period from the utility usage. To do so, in the illustrative embodiment, the total greenhouse gas emissions from the utility usage for the reference/reporting period is determined based on the following Equation (25):

[00174]
$$GHG_{\text{fuel\&electricity}} = GHG_{\text{fuel}} + GHG_{\text{electricity}} \quad (25)$$

[00175] wherein $GHG_{\text{fuel\&electricity}}$ is the total greenhouse gas emissions from fuel and electricity usage during the reporting period (kg CO₂e), GHG_{fuel} is the total greenhouse gas emissions from fuel usage during the reporting period (kg CO₂e), and $GHG_{\text{electricity}}$ is the total greenhouse gas emissions from electricity usage during the reporting period (kg CO₂e).

[00176] The total greenhouse gas emissions from fuel usage during the reporting period, GHG_{fuel} , is determined based on the following Equation (26):

$$[00177] \quad GHG_{fuel} = \sum_T F_T \times (EF_{comb_T} + EF_{ext_T}) \quad (26)$$

[00178] wherein GHG_{fuel} is the total greenhouse gas emissions from fuel usage during the reporting period (kg CO₂e), F_T is the fuel use for fuel type T during the reported period (units according to fuel type presented in table 2600 of FIG. 26), EF_{comb_T} is the emissions factor for the combustion of fuels for fuel type T (kg CO₂e / fuel type unit; EIA value), and EF_{ext_T} is the emissions factor for the extraction and processing of fuels for fuel type T (Rotz et al., 2019).

[00179] The total greenhouse gas emissions from electricity usage during the reporting period, $GHG_{electricity}$, is determined using the following Equation (27):

$$[00180] \quad GHG_{electricity} = U \times \left(\frac{eGRID}{2.20462 \times 1000} \right) \quad (27)$$

[00181] where $GHG_{electricity}$ is the total greenhouse gas emissions from electricity usage during the reporting period (kg CO₂e), U is the electricity usage during the reporting period (kWh), $eGRID$ is the state specific emission factor obtained from the EPA Emissions & Generation Resource Integrated Database (lb/MWh), 2.20462 is lb per kg, and 1000 is kWh per MWh.

[00182] Referring again to FIG. 2, the mathematical model 200 includes a total greenhouse gas emissions from controllable sources submodel 220, which determines the total greenhouse gas emissions of the cattle farm operation based on the output of the sub-modules 210, 212, 214, and 216 according to the following Equation (28):

$$[00183] \quad GHG_P^T = GHG_{feed,P}^T + GHG_{ent,P}^T + GHG_{man,P}^T + GHG_{f\&e,P}^T \quad (28)$$

[00184] wherein GHG_P^T is the total greenhouse gas emissions for the cattle type T, $GHG_{feed,P}^T$ is the GHG emissions from the cultivation of feed fed during the reporting period, $GHG_{ent,P}^T$ is the GHG emissions from enteric fermentation from cattle type T during the reporting period, $GHG_{man,P}^T$ is the total GHG emissions from manure management for during the reporting period, and $GHG_{f\&e,P}^T$ is the total greenhouse gas emissions from fuel and electricity usage during the reporting period.

[00185] The output of the sub-model 220, GHG_P^T , is provide to a greenhouse gas reduction sub-model 240, which also receives a baseline greenhouse gas emission from a baseline model 242. The baseline greenhouse gas emission may be a default amount of greenhouse gas emission or may be determined for a prior reference/reporting period for that cattle farm operation. The greenhouse gas reduction sub-model 240 determines the greenhouse gas emission reduction for

the cattle farm operation due to the remediation procedures (e.g., the feed additives) using the following Equation (29):

$$[00186] \quad \Delta GHG = \sum_T (GHG_B^T - GHG_P^T) \quad (29)$$

[00187] wherein ΔGHG is the net greenhouse gas emissions after implementation of the technologies described herein (e.g., the addition of the feed additives), GHG_B^T is baseline greenhouse gas emissions for the cattle type T determined by sub-model 242, and GHG_P^T is total greenhouse gas emissions for the cattle type T determined by sub-model 220.

[00188] In some embodiments, the total controllable greenhouse gas emissions model 200 may also include an allocation sub-model 230 configured to allocate the is total greenhouse gas emissions for the cattle type T determined by sub-model 220. In such embodiments, the allocation sub-model 230 may include a greenhouse gas from milk and meat production sub-model 232, which is configured to allocate the determined greenhouse gas emissions using the following Equations (30) and (31):

$$[00189] \quad AF_{meat_i} = \frac{NE_L \times M_{milk}}{NE_L \times M_{milk} + \sum_i NE_{G_i} \times M_{class_i}} \quad (30)$$

$$[00190] \quad AF_{meat_i} = \frac{NE_{G_i} \times M_{class_i}}{NE_L \times M_{milk} + \sum_i NE_{G_i} \times M_{class_i}} \quad (31)$$

[00191] wherein AF_{milk} is the allocation factor for milk (fraction of total dairy carbon footprint allocated to milk production), AF_{meat_i} is the allocation factor for meat class i (fraction of total dairy carbon footprint allocated to meat production from meat class i), NE_L is the net energy requirement of lactation (3.1 MJ/kg fat- and protein-corrected milk; Nemecek and Thoma, 2020), M_{milk} is the total weight of fat- and protein-corrected milk (kg), NE_{G_i} is the net energy requirement of gain for cattle meat class i (which may be determined according to Nemecek and Thoma (2020) and IDF (2022)), and M_{class_i} is the total liveweight produced for cattle meat class i (kg). The total meat allocation factor is a summation of the allocation factor for all meat classes.

[00192] Additionally, the allocation sub-model 230 may include a greenhouse gas from utility usage based on cattle type sub-model 234, which is configured to allocate the utility usage based on the cattle type using the following Equation (32):

$$[00193] \quad AF_{FuelElectric_T} = \frac{GHG_{FuelElectric} \times DMI_T}{\sum_T DMI_T} \quad (3)$$

[00194] wherein $AF_{FuelElectric_T}$ is the fuel and electric allocation factor for cattle type T (fraction of total emissions associated with fuel and electricity that is allocated to each cattle type), $GHG_{FuelElectric}$ is the total GHG emission from fuel and electricity (kg CO₂e), and DMI_T is the dry matter intake for cattle type T (kg).

[00195] Referring again to FIG. 2 and as discussed above, the total controllable emission model 200 is configured to produce a set of greenhouse gas emission metrics based on the total greenhouse gas emission determined by sub-model 220 and the total reduction in greenhouse gas emission determined by sub-model 240. Based on those metrics, the model 200 may be configured to submit the greenhouse gas metrics for carbon credits. Additionally, the model 200 may produce a set of greenhouse remediation recommendations (e.g., the addition of a feed additive) based on the total greenhouse gas emission determined by sub-model 220 and the total reduction in greenhouse gas emission determined by sub-model 240.

[00196] Referring now to FIG. 3, in the illustrative embodiment, the GHG monitoring server 102 is configured to establish an environment 300 during operation. The illustrative environment 300 includes a communication manager, a greenhouse gas estimator 304, and a greenhouse gas metrics determiner 316, along with greenhouse gas database 320 and an equation or model database 322. The various components of the environment 300 may be embodied as hardware, firmware, software, or a combination thereof. As such, in some embodiments, one or more of the components of the environment 300 may be embodied as circuitry or a collection of electrical devices (e.g., greenhouse gas metrics determiner circuitry 316, greenhouse gas estimator circuitry 304, and greenhouse gas metrics determiner circuitry 316, etc.) It should be appreciated that, in such embodiments, one or more of those components may form a portion of the processor 122, the I/O subsystem 126, and/or other components of the GHG monitoring server 102.

[00197] The communication manager 302 is configured to manage communications between the GHG monitoring server 102 and the user computer device 104. To do so, the communication manager 302 may utilize any suitable communication protocol.

[00198] The greenhouse gas emissions estimator 304 is configured to determine a total greenhouse gas emission for the cattle farm operation based on the various inputs received from the user computer device 104. To do so, the greenhouse gas emissions estimator 304 includes a feed cultivation greenhouse gas emissions estimator 306, an enteric fermentation greenhouse gas emissions estimator 308, a manure management greenhouse gas emissions estimator 310, and a utility usage greenhouse gas emissions estimator 312. The feed cultivation greenhouse gas emissions estimator 306 is configured to determine the total greenhouse gas emission of the cattle farm operation due to feed cultivation using the sub-model 210 and associated equations discussed above. Similarly, the enteric fermentation greenhouse gas emissions estimator 308 is configured to determine the total greenhouse gas emission of the cattle farm operation due to

enteric fermentation using the sub-model 212 and associated equations discussed above. The manure management greenhouse gas emissions estimator 310 is configured to determine the total greenhouse gas emission of the cattle farm operation due to manure management using the sub-model 214 and associated equations discussed above. The utility usage greenhouse gas emissions estimator 312 is configured to determine the total greenhouse gas emission of the cattle farm operation due to utility usage using the sub-model 216 and associated equations discussed above.

[00199] The greenhouse gas emissions metrics determiner 316 is configured to generate the set of greenhouse gas emission metrics based on the total greenhouse gas emission determined by sub-model 220 and the total reduction in greenhouse gas emission determined by sub-model 240. As discussed above, the greenhouse gas emission metrics may provide a comparison to a baseline or historical greenhouse gas emission metrics of the cattle farm operation, which may provide the user with actionable data to improve the carbon footprint of the cattle farm operation, as well as request carbon credit for any reductions. The determined greenhouse gas emissions data may be stored in the greenhouse gas database 320 and the various mathematical models used by the greenhouse gas monitoring server 102 may be stored in the model database 322.

[00200] Referring now to FIG. 4, in the illustrative embodiment, the user computer device 104 is configured to establish an environment 400 during operation. The illustrative environment 400 includes a communication manager 402 and a greenhouse gas database 420. Additionally, in some embodiments, the environment 400 may also include a herd management interface 404, a feed management interface 406, a utility management interface 408, and a sensor management interface 410. The various components of the environment 400 may be embodied as hardware, firmware, software, or a combination thereof. As such, in some embodiments, one or more of the components of the environment 400 may be embodied as circuitry or a collection of electrical devices (e.g., communication manager circuitry 402, herd management interface circuitry 404, feed management interface circuitry 406, utility management interface circuitry 408, and a sensor management interface circuitry 410, etc.) It should be appreciated that, in such embodiments, one or more of those components may form a portion of the processor 152, the I/O subsystem 156, and/or other components of the respective user computer device 104.

[00201] The communication manager 402 is configured to manage communications between the user computer device 104 and the GHG monitoring server 102. To do so, the communication manager 402 may utilize any suitable communication protocol.

[00202] The herd management interface 404 is configured to interface with the herd management system 110 to receive herd management data therefrom. Similarly, the feed

management interface 406 is configured to interface with the feed management system 112 to receive feed management data therefrom, and the utility management interface 408 is configured to interface with the utility management system 114 to receive herd management data therefrom. The sensor management interface 410 is configured to interface with the sensor(s) 118 and may form a portion of the herd management system 110, the feed management system 112, and/or the utility management system 114

[00203] Referring now to FIGS. 5A-5C, in use, the GHG monitoring server 102 may execute a method 500 method for managing a carbon footprint of a cattle farm operation. It should be appreciated that, in some embodiments, the operations of the method 500 may be performed by one or more components of the environment 300 of the GHG monitoring server 102 as shown in FIG. 3.

[00204] The method 500 begins with block 502, in which the GHG monitoring server 102 determines whether a login request has been received. If so, the method 500 advances to block 504, in which the GHG monitoring server 102 logs the user into the server 102. In doing so, the GHG monitoring server 102 may display a user interface 600 to the user on the user computer device 104. The illustrative user interface 600 allows the user to select various links to enter baseline greenhouse gas emissions data form the cattle farm operation, as well as new inputs for the present reporting/reference period (e.g., for the present month). Those new inputs include feed ingredient usage, utility usage, and demographics and productivity as shown in FIG. 6.

[00205] Referring back to FIG. 5A, after the user has been logged in in block 504, the method 500 advances to block 506 in which the GHG monitoring server 102 determines whether a set of baseline (or historical) greenhouse gas emissions have been established yet. If not, the method 500 advances to block 508 in which the GHG monitoring server 102 receives the baseline (or historical) greenhouse gas emissions information from the user. For example, in block 510, the GHG monitoring server 102 may receive farm contact data. To do so, the GHG monitoring server 102 may display a user interface 700 as shown in FIG. 7 to the user on the user computer device 104. The user interface 700 provides data cells in which the user may supply the contact information for the cattle farm operation.

[00206] Referring back to FIG. 5A, in block 512, the GHG monitoring server 102 may require the user to execute one or more user agreements for using the services of the GHG monitoring server 102. Additionally, in block 514, the GHG monitoring server 102 may receive replacement heifer data from the user. For example, in block 516, the GHG monitoring server 102 may receive replacement heifer feeding information. To do so, the GHG monitoring server

102 may display a user interface 800 to the user on the user computer device 104 as shown in FIG. 8. The user interface 800 provides data cells in which the user can supply various information related to the replacement heifers including whether the replacement heifers were raised on-site for the entire heifer development period, the average daily feed in rate for milk and/or mil replacer for pre-weaned calves, and the average proportion of the milk fed to the pre-weaned that is milk replacer.

[00207] Referring back to FIG. 5A, in block 518, the GHG monitoring server 102 may receive manure management data from the user. For example, in block 520, the GHG monitoring server 102 may receive percentage data of manure management type used for each cattle type from the user. To do so, the GHG monitoring server 102 may display a user interface 900 to the user on the user computer device 104 as shown in FIG. 9. The user interface 900 provides data cells in which the user can identify the percentage of the herd managed by each manure management type (e.g., dry lots, uncovered anaerobic lagoon, anaerobic digester, etc.).

[00208] Referring again back to FIG. 5A, in block 522, the GHG monitoring server 102 may receive and/or verify historical input and output data for the cattle farm operation. In some embodiments, the historical input/output data may form the baseline greenhouse gas emissions data. For example, in block 524, the GHG monitoring server 102 may receive and/or verify the historical head count for each cattle. Additionally, in block 526, the GHG monitoring server 102 may receive and/or verify the daily dry matter intake for each cattle. Furthermore, in block 528, the GHG monitoring server 102 may receive and/or verify the milk production for lactating cattle type. To receive and/or verify such information, the GHG monitoring server 102 may be configured to display a user interface 1000 to the user on the user interface device 104. The user interface 100 displays the historical/baseline data including the cattle type, head count, daily dry matter intake, and milk production for each cattle type of the cattle farm operation.

[00209] Referring back to FIG. 5A, after the GHG monitoring server 102 has received and verified the baseline/historic greenhouse gas emissions data in block 508 or if the baseline/historical greenhouse gas emissions data has already been established in block 506, the method 500 advances to block 530. In block 530, the GHG monitoring server 102 determines whether the user desires to submit new greenhouse gas emissions data for the present reporting period. In doing so, the GHG monitoring server 102 may display a user interface 1100 (similar to user interface 600) to the user on the user computer device 104. From the user interface 110, the user may select to submit feed ingredient usage data, utility usage data, and/or demographics and productivity data for the reporting period (e.g., for the present month). If so, the method 500

advances to block 532 of FIG. 5B. In block 532, the GHG monitoring server 102 receives feed ingredient usage data from each cattle type for the reporting/reference time period. For example, in block 534, the GHG monitoring server 102 receives a diet identifier 534. Additionally, in block 536, the GHG monitoring server 102 receives an indication of any feed additive for the present diet. To do so, the GHG monitoring server 102 may present a user interface 1200 to the user on the user computer device 104 as shown in FIG. 12. The user interface 1200 allows the user to enter a diet identifier for each cattle type (e.g., lactating, dry, heifers). Additionally, the user may select an indicator to indicate whether any feed additive and which type of feed additive is included in that particular diet.

[00210] Referring back to FIG. 5B, in block 538, the GHG monitoring server 102 receives the ingredient type(s) for the present data. For example, in block 540, the GHG monitoring server 102 receives the ingredient amount for each identified ingredient. To do so, the GHG monitoring server 102 may present a user interface 1300 as shown in FIG. 13 and a user interface 1400 as shown in FIG. 14 to the user on the user computer device 104. The user interface 1300 allows the user to add additional ingredients and select the ingredient type from a drop-down menu. The user interface 1400 allows the user to enter the amount of each identified ingredient.

[00211] Referring back to FIG. 5B, after the user has supplied the feed ingredient usage data or if the user does not provide such data, the method 500 advances to block 542. In block 542, the GHG monitoring server 102 receives utility usage data for the reporting time period from the user. For example, in block 544, the GHG monitoring server 102 receives a utility identifier for each utility used. In block 546, the GHG monitoring server 102 receives the usage amount and the utility type for each identified utility. Additionally, in block 548, the GHG monitoring server 102 receives the percentage of each identified utility used for dairy operations. To do so, the GHG monitoring server 102 may present a user interface 1500 as shown in FIG. 15. The user interface 1500 includes data cells and drop-down windows that allow the user to submit the utility type, the total units used and the unit type, as well as the percentage of the energy used for dairy operations.

[00212] Referring back to FIG. 5B again, after the user has supplied the utility usage data or if the user does not provide such data, the method 500 advances to block 550. In block 550, the GHG monitoring server 102 receives herd demographics and productivity data for the reporting/reference time period. For example, in block 522, the GHG monitoring server 102 receives population data for each cattle type. Additionally, in some embodiments, the GHG monitoring server 102 may receive sales data for each cattle type since the last report period in

block 554. To do so, the GHG monitoring server 102 may present a user interface 1600 as shown in FIG. 16. The user interface 1600 includes data cells for each cattle type in which the user can submit the present population number. Additionally, the user interface 600 includes data cells in which the user can supply the number and weight of sold cattle.

[00213] Referring back to FIG. 5B, in block 556, the GHG monitoring server 102 receives breed data from each cattle from the user. For example, in block 558, the GHG monitoring server 102 may receive percentage data for each identified breed. To do so, the GHG monitoring server 102 may present a user interface 1700 as shown in FIG. 17. The user interface 1700 includes data cells in which the user can identify the percentage of each breed of each different cattle type.

[00214] Referring again back to FIG. 5B, in block 560, the GHG monitoring server 102 receives milk production data for lactating cattle type. For example in block 562, the GHG monitoring server 102 receives production amount data for each identified milk type. To do so, the GHG monitoring server 102 may present a user interface 1700 as shown in FIG. 17. The user interface 1800 includes data cells in which the user can identify the total value of production of each milk type for the present reporting period.

[00215] Referring back to FIG. 5B, after the user has supplied the herd demographics and productivity data for the present reporting period (or if not is being provided), the method 500 advances to block 564 of FIG. 5C. In block 564, the GHG monitoring server 102 determines an estimate of total greenhouse gas emissions produced by controllable sources of the cattle farm operation. To do so, the GHG monitoring server 102 utilizes the total controllable greenhouse emission model 200 described above in regard to FIG. 2. For example, in block 566, the GHG monitoring server 102 may determine an estimate of greenhouse gas emission from feed cultivation using the sub-model 210 of the model 200 as described above. Additionally, in block 568, the GHG monitoring server 102 may determine an estimate of greenhouse gas emission from enteric fermentation using the sub-model 212 of the model 200 as described above. Furthermore, in block 570, the GHG monitoring server 102 may determine an estimate of greenhouse gas emission from manure management using the sub-model 214 of the model 200 as described above. Additionally, in block 572, the GHG monitoring server 102 may determine an estimate of greenhouse gas emission from utility usage using the sub-model 216 of the model 200 as described above.

[00216] In some embodiments, in block 574, the GHG monitoring server 102 may be configured to allocate portions of the total greenhouse gas emissions. For example, in blocks 576 and 578, the GHG monitoring server 102 may allocate the estimated total greenhouse gas

emissions due to milk and meat production using the sub-model 232 of the model 200 as described above. Additionally, in block 580, the GHG monitoring server 102 may allocate the estimated utility usage based on cattle type using the sub-model 234 of the model 200 as described above.

[00217] In block 582, the GHG monitoring server 102 determines a reduction in the greenhouse gas emissions relative the baseline/historical emission. To do so, the GHG monitoring server 102 uses the sub-model 240 of the model 200 described above in regard to FIG. 2 to determine the reduction of greenhouse gas emissions, at least some of which may be caused by the feed additive(s).

[00218] In block 584, the GHG monitoring server 102 generates greenhouse gas emission metrics based on the estimated total greenhouse gas emissions and the estimated reduction in total greenhouse gas emissions. Such metrics may be shown as a comparison the baseline/historic data. For example, the GHG monitoring server 102 may present a user interface 1900 as shown in FIG. 19, a user interface 2000 as shown in FIG. 20, and/or a user interface 2100 as shown in FIG. 21. The user interface 2100 illustrates the carbon footprint of the cattle farm operation by emission source. Additionally, the GHG monitoring server 102 may also determine one or more greenhouse gas emission remediation recommendation in block 586 of FIG. 5C.

[00219] After the GHG monitoring server 102 has generated and displayed the metrics to the user, the method 500 advances to block 588 in which the GHG monitoring server 102 determines whether the user desires to submit the greenhouse gas emissions metrics for carbon credit. If so, the method 500 advances to block 590 in which the GHG monitoring server 102 submits the metrics for carbon credit. For example, if the metrics indicate a reduction in greenhouse gas emissions relative to a historical reporting period, the cattle feed operation may receive a carbon credit for such reduction. In this way, the described system and methodologies can support the receipt of carbon credit for a cattle farm operation using the described feed additives.

[00220] While the disclosure has been illustrated and described in detail in the drawings and foregoing description, such an illustration and description is to be considered as illustrative and not restrictive in character, it being understood that only illustrative embodiments have been shown and described and that all changes and modifications that come within the spirit of the disclosure are desired to be protected.

[00221] There are a plurality of advantages of the present disclosure arising from the various features of the methods, apparatuses, and systems described herein. It will be noted that

alternative embodiments of the methods, apparatuses, and systems of the present disclosure may not include all of the features described yet still benefit from at least some of the advantages of such features. Those of ordinary skill in the art may readily devise their own implementations of the methods, apparatuses, and systems that incorporate one or more of the features of the present invention and fall within the spirit and scope of the present disclosure as defined by the appended claims.

WHAT IS CLAIMED IS:

1. A method for managing a carbon footprint of a cattle farm operation having a cattle herd comprising one or more cattle type, the method comprising:

receiving, by a server computer and for a reference time period of the cattle farm operation, feed ingredient usage data for each cattle type of the cattle herd, wherein the feed ingredient usage data includes an amount of feed provided for each cattle type of the cattle herd and identification of a feed additive included in the feed, wherein the feed additive is configured to reduce an amount of greenhouse gas emissions produced by each cattle of the cattle herd that consumes the feed;

determining, by the server computer and for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using a model of total controllable greenhouse gas emissions with the feed ingredient usage data as an input to the model; and

requesting, by the server computer and for the reference time period of the cattle farm operation, a carbon credit based on the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation.

2. The method of claim 1, wherein the feed additive is monensin.

3. The method of claim 1, wherein the feed additive is 3-nitrooxypropanol.

4. The method of claim 1, wherein the greenhouse gas emissions comprises methane.

5. The method of claim 1, where the cattle herd includes dairy cattle.

6. The method of claim 1, wherein the cattle herd include beef cattle.

7. The method of claim 1, wherein the feed additive is configured to reduce the amount of greenhouse emissions produced by each cattle of the cattle herd that consumes the feed by reducing enteric fermentation of each cattle.

8. The method of claim 1, wherein the feed additive is configured to reduce the amount of greenhouse emissions produced by each cattle of the cattle herd that consumes the feed by decreasing dry matter intake (DMI) of each cattle.

9. The method of claim 1, wherein the amount of feed provided for each cattle type comprises a plurality of ingredients and a corresponding amount of each ingredient of the plurality of ingredients.

10. The method of claim 1, further comprising receiving, by the server computer and for the reference time period of the cattle farm operation, utility usage data indicative of an amount of a utility service used by the cattle farm operation,

wherein determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable greenhouse gas emissions with (i) the feed ingredient usage data and (ii) the utility usage data as inputs to the model.

11. The method of claim 10, wherein receiving the utility usage data comprises receiving a percentage of usage of the utility service used for dairy operations of the cattle farm operation.

12. The method of claim 10, further comprising receiving, by the server computer and for the reference time period of the cattle farm operation, herd demographics data indicative of the population and breed of the cattle herd,

wherein determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable greenhouse gas emissions with (i) the feed ingredient usage data, (ii) the utility usage data, and (iii) the herd demographics data as inputs to the model.

13. The method of claim 12, wherein receiving the herd demographics data includes receiving sales data indicative of a number of cattle sold from the cattle herd.

14. The method of claim 12, further comprising receiving, by a server computer and for the reference time period of the cattle farm operation, milk production data that identifies an amount of milk type produced by each lactating cattle type of the cattle herd;

wherein determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable greenhouse gas emissions with (i) the feed ingredient usage data, (ii) the utility usage data, (iii) the herd demographics data, and (iv) the milk production data as inputs to the model.

15. The method of claim 1, wherein determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises:

determining, by the server computer and for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation; and

determining, by the server computer and for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to feed cultivation.

16. The method of claim 1, wherein determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises:

determining, by the server computer and for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd; and

determining, by the server computer and for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd.

17. The method of claim 1, wherein determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises:

determining, by the server computer and for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to manure management of the cattle farm operation; and

determining, by the server computer and for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to manure management of the cattle farm operation.

18. The method of claim 1, wherein determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises:

determining, by the server computer and for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation; and

determining, by the server computer and for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation.

19. The method of claim 1, wherein determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises:

determining, by the server computer and for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation;

determining, by the server computer and for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd;

determining, by the server computer and for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to manure management of the cattle farm operation;

determining, by the server computer and for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation; and

determining, by the server computer and for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on (i) the estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation, (ii) the estimated amount of greenhouse gas emission due to enteric

fermentation of the cattle herd, (iii) the estimated amount of greenhouse gas emission due to manure management of the cattle farm operation, and (iv) the estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation.

20. The method of claim 1, wherein determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprising allocating the estimated total amount of controllable greenhouse gas emissions between milk production operations of the cattle farm operation and meat production operations of the cattle farm operation.

21. The method of claim 20, wherein determining the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation further comprises allocating utility usage indicative of an amount of utility service used by the cattle farm operation based on cattle type of the cattle herd.

22. The method of claim 1, wherein requesting the carbon credit comprises:
determining a reduction of greenhouse gas emissions based on the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation and a baseline greenhouse gas emissions amount, and
requesting, by the server computer and for the reference time period of the cattle farm operation, the carbon credit based on the determined reduction of greenhouse gas emissions.

23. The method of claim 1, further comprises:
generating greenhouse gas emissions metrics based on the estimated total amount of controllable greenhouse gas emissions; and
displaying the greenhouse gas emissions metrics to a user.

24. The method of claim 23, wherein the greenhouse gas emissions metrics includes indicia of a comparison of the estimated total amount of controllable greenhouse gas emissions for the reference time period and a prior time period.

25. The method of claim 24, wherein the estimated total amount of controllable greenhouse gas emissions includes a plurality of greenhouse gas emission types and wherein the greenhouse gas emissions metrics identifies an amount of each greenhouse gas emission type.

26. The method of claim 1, further comprising determining a recommended greenhouse gas emission remediation action for the cattle farm operation based on the estimated total amount of controllable greenhouse gas emissions.

27. A server computer for managing a carbon footprint of a cattle farm operation having a cattle herd comprising one or more cattle type, the server computer comprising:

a processor; and

a memory having stored therein a plurality of instructions that, when executed by the processor, cause the server computer to:

receive, for a reference time period of the cattle farm operation, feed ingredient usage data for each cattle type of the cattle herd, wherein the feed ingredient usage data includes an amount of feed provided for each cattle type of the cattle herd and identification of a feed additive included in the feed, wherein the feed additive is configured to reduce an amount of greenhouse gas emissions produced by each cattle of the cattle herd that consumes the feed;

determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using a model of total controllable greenhouse gas emissions with the feed ingredient usage data as an input to the model; and

request, for the reference time period of the cattle farm operation, a carbon credit based on the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation.

28. The server computer of claim 27, wherein the feed additive is monensin.

29. The server computer of claim 27, wherein the feed additive is 3-nitrooxypropanol.

30. The server computer of claim 27, wherein the greenhouse gas emissions comprises methane.

31. The server computer of claim 27, where the cattle herd includes dairy cattle.
32. The server computer of claim 27, wherein the cattle herd include beef cattle.
33. The server computer of claim 27, wherein the feed additive is configured to reduce the amount of greenhouse emissions produced by each cattle of the cattle herd that consumes the feed by reducing enteric fermentation of each cattle.
34. The server computer of claim 27, wherein the feed additive is configured to reduce the amount of greenhouse emissions produced by each cattle of the cattle herd that consumes the feed by decreasing dry matter intake (DMI) of each cattle.
35. The server computer of claim 27, wherein the amount of feed provided for each cattle type comprises a plurality of ingredients and a corresponding amount of each ingredient of the plurality of ingredients.
36. The server computer of claim 27, wherein the plurality of instructions, when executed by the processor, further cause the server computer to receive, for the reference time period of the cattle farm operation, utility usage data indicative of an amount of a utility service used by the cattle farm operation,
wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable greenhouse gas emissions with (i) the feed ingredient usage data and (ii) the utility usage data as inputs to the model.
37. The server computer of claim 36, wherein to receive the utility usage data comprises to receive a percentage of usage of the utility service used for dairy operations of the cattle farm operation.
38. The server computer of claim 36, wherein the plurality of instructions, when executed by the processor, further cause the server computer to receive, for the reference time

period of the cattle farm operation, herd demographics data indicative of the population and breed of the cattle herd,

wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable greenhouse gas emissions with (i) the feed ingredient usage data, (ii) the utility usage data, and (iii) the herd demographics data as inputs to the model.

39. The server computer of claim 38, wherein to receive the herd demographics data includes to receive sales data indicative of a number of cattle sold from the cattle herd.

40. The server computer of claim 38, wherein the plurality of instructions, when executed by the processor, further cause the server computer to receive, for the reference time period of the cattle farm operation, milk production data that identifies an amount of milk type produced by each lactating cattle type of the cattle herd;

wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable greenhouse gas emissions with (i) the feed ingredient usage data, (ii) the utility usage data, (iii) the herd demographics data, and (iv) the milk production data as inputs to the model.

41. The server computer of claim 27, wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises to:

determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation; and

determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to feed cultivation.

42. The server computer of claim 27, wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises to:

determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd; and

determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd.

43. The server computer of claim 27, wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises to:

determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to manure management of the cattle farm operation; and

determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to manure management of the cattle farm operation.

44. The server computer of claim 27, wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises to:

determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation; and

determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation.

45. The server computer of claim 27, wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises to:

determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation;

determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd;

determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to manure management of the cattle farm operation;

determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation; and

determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on (i) the

estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation, (ii) the estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd, (iii) the estimated amount of greenhouse gas emission due to manure management of the cattle farm operation, and (iv) the estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation.

46. The server computer of claim 27, wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprising to allocate the estimated total amount of controllable greenhouse gas emissions between milk production operations of the cattle farm operation and meat production operations of the cattle farm operation.

47. The server computer of claim 46, wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation further comprises to allocate utility usage indicative of an amount of utility service used by the cattle farm operation based on cattle type of the cattle herd.

48. The server computer of claim 27, wherein to request the carbon credit comprises to:

determine a reduction of greenhouse gas emissions based on the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation and a baseline greenhouse gas emissions amount, and

request, for the reference time period of the cattle farm operation, the carbon credit based on the determined reduction of greenhouse gas emissions.

49. The server computer of claim 27, further comprises to:

generate greenhouse gas emissions metrics based on the estimated total amount of controllable greenhouse gas emissions; and

display the greenhouse gas emissions metrics to a user.

50. The server computer of claim 49, wherein the greenhouse gas emissions metrics includes indicia of a comparison of the estimated total amount of controllable greenhouse gas emissions for the reference time period and a prior time period.

51. The server computer of claim 50, wherein the estimated total amount of controllable greenhouse gas emissions includes a plurality of greenhouse gas emission types and wherein the greenhouse gas emissions metrics identifies an amount of each greenhouse gas emission type.

52. The server computer of claim 27, wherein the plurality of instructions, when executed by the processor, further cause the server computer to determine a recommended greenhouse gas emission remediation action for the cattle farm operation based on the estimated total amount of controllable greenhouse gas emissions.

53. One or more non-transitory, computer-readable storage media comprising a plurality of instructions that, in response to execution, cause a server computer to:

receive, for a reference time period of the cattle farm operation, feed ingredient usage data for each cattle type of the cattle herd, wherein the feed ingredient usage data includes an amount of feed provided for each cattle type of the cattle herd and identification of a feed additive included in the feed, wherein the feed additive is configured to reduce an amount of greenhouse gas emissions produced by each cattle of the cattle herd that consumes the feed;

determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using a model of total controllable greenhouse gas emissions with the feed ingredient usage data as an input to the model; and

request, for the reference time period of the cattle farm operation, a carbon credit based on the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation.

54. The one or more non-transitory, computer-readable storage media of claim 53, wherein the feed additive is monensin.

55. The one or more non-transitory, computer-readable storage media of claim 53, wherein the feed additive is 3-nitrooxypropanol.

56. The one or more non-transitory, computer-readable storage media of claim 53, wherein the greenhouse gas emissions comprises methane.

57. The one or more non-transitory, computer-readable storage media of claim 53, where the cattle herd includes dairy cattle.

58. The one or more non-transitory, computer-readable storage media of claim 53, wherein the cattle herd include beef cattle.

59. The one or more non-transitory, computer-readable storage media of claim 53, wherein the feed additive is configured to reduce the amount of greenhouse emissions produced by each cattle of the cattle herd that consumes the feed by reducing enteric fermentation of each cattle.

60. The one or more non-transitory, computer-readable storage media of claim 53, wherein the feed additive is configured to reduce the amount of greenhouse emissions produced by each cattle of the cattle herd that consumes the feed by decreasing dry matter intake (DMI) of each cattle.

61. The one or more non-transitory, computer-readable storage media of claim 53, wherein the amount of feed provided for each cattle type comprises a plurality of ingredients and a corresponding amount of each ingredient of the plurality of ingredients.

62. The one or more non-transitory, computer-readable storage media of claim 53, wherein the plurality of instructions, when executed by the processor, further cause the server computer to receive, for the reference time period of the cattle farm operation, utility usage data indicative of an amount of a utility service used by the cattle farm operation,

wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable greenhouse gas emissions with (i) the feed ingredient usage data and (ii) the utility usage data as inputs to the model.

63. The one or more non-transitory, computer-readable storage media of claim 62, wherein to receive the utility usage data comprises to receive a percentage of usage of the utility service used for dairy operations of the cattle farm operation.

64. The one or more non-transitory, computer-readable storage media of claim 62, wherein the plurality of instructions, when executed by the processor, further cause the server computer to receive, for the reference time period of the cattle farm operation, herd demographics data indicative of the population and breed of the cattle herd,

wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable greenhouse gas emissions with (i) the feed ingredient usage data, (ii) the utility usage data, and (iii) the herd demographics data as inputs to the model.

65. The one or more non-transitory, computer-readable storage media of claim 64, wherein to receive the herd demographics data includes to receive sales data indicative of a number of cattle sold from the cattle herd.

66. The one or more non-transitory, computer-readable storage media of claim 64, wherein the plurality of instructions, when executed by the processor, further cause the server computer to receive, for the reference time period of the cattle farm operation, milk production data that identifies an amount of milk type produced by each lactating cattle type of the cattle herd;

wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation using the model of total controllable greenhouse gas emissions with (i) the feed ingredient usage data, (ii) the utility usage data, (iii) the herd demographics data, and (iv) the milk production data as inputs to the model.

67. The one or more non-transitory, computer-readable storage media of claim 53, wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises to:

determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation; and

determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to feed cultivation.

68. The one or more non-transitory, computer-readable storage media of claim 53, wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises to:

determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd; and

determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd.

69. The one or more non-transitory, computer-readable storage media of claim 53, wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises to:

determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to manure management of the cattle farm operation; and

determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to manure management of the cattle farm operation.

70. The one or more non-transitory, computer-readable storage media of claim 53, wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises to:

determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation; and

determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on the estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation.

71. The one or more non-transitory, computer-readable storage media of claim 53, wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprises to:

determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation;

determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd;

determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to manure management of the cattle farm operation;

determine, for the reference time period of the cattle farm operation, an estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation; and

determine, for the reference time period of the cattle farm operation, an estimated total amount of controllable greenhouse gas emissions for the cattle farm operation based on (i) the estimated amount of greenhouse gas emission due to feed cultivation of the dairy farm operation, (ii) the estimated amount of greenhouse gas emission due to enteric fermentation of the cattle herd, (iii) the estimated amount of greenhouse gas emission due to manure management of the cattle farm operation, and (iv) the estimated amount of greenhouse gas emission due to utility usage of the cattle farm operation.

72. The one or more non-transitory, computer-readable storage media of claim 53, wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation comprising to allocate the estimated total amount of controllable greenhouse gas emissions between milk production operations of the cattle farm operation and meat production operations of the cattle farm operation.

73. The one or more non-transitory, computer-readable storage media of claim 72, wherein to determine the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation further comprises to allocate utility usage indicative of an amount of utility service used by the cattle farm operation based on cattle type of the cattle herd.

74. The one or more non-transitory, computer-readable storage media of claim 53, wherein to request the carbon credit comprises to:

determine a reduction of greenhouse gas emissions based on the estimated total amount of controllable greenhouse gas emissions for the cattle farm operation and a baseline greenhouse gas emissions amount, and

request, for the reference time period of the cattle farm operation, the carbon credit based on the determined reduction of greenhouse gas emissions.

75. The one or more non-transitory, computer-readable storage media of claim 53, further comprises to:

generate greenhouse gas emissions metrics based on the estimated total amount of controllable greenhouse gas emissions; and

display the greenhouse gas emissions metrics to a user.

76. The one or more non-transitory, computer-readable storage media of claim 75, wherein the greenhouse gas emissions metrics includes indicia of a comparison of the estimated total amount of controllable greenhouse gas emissions for the reference time period and a prior time period.

77. The one or more non-transitory, computer-readable storage media of claim 76, wherein the estimated total amount of controllable greenhouse gas emissions includes a plurality of greenhouse gas emission types and wherein the greenhouse gas emissions metrics identifies an amount of each greenhouse gas emission type.

78. The one or more non-transitory, computer-readable storage media of claim 53, wherein the plurality of instructions, when executed by the processor, further cause the server computer to determine a recommended greenhouse gas emission remediation action for the cattle farm operation based on the estimated total amount of controllable greenhouse gas emissions.

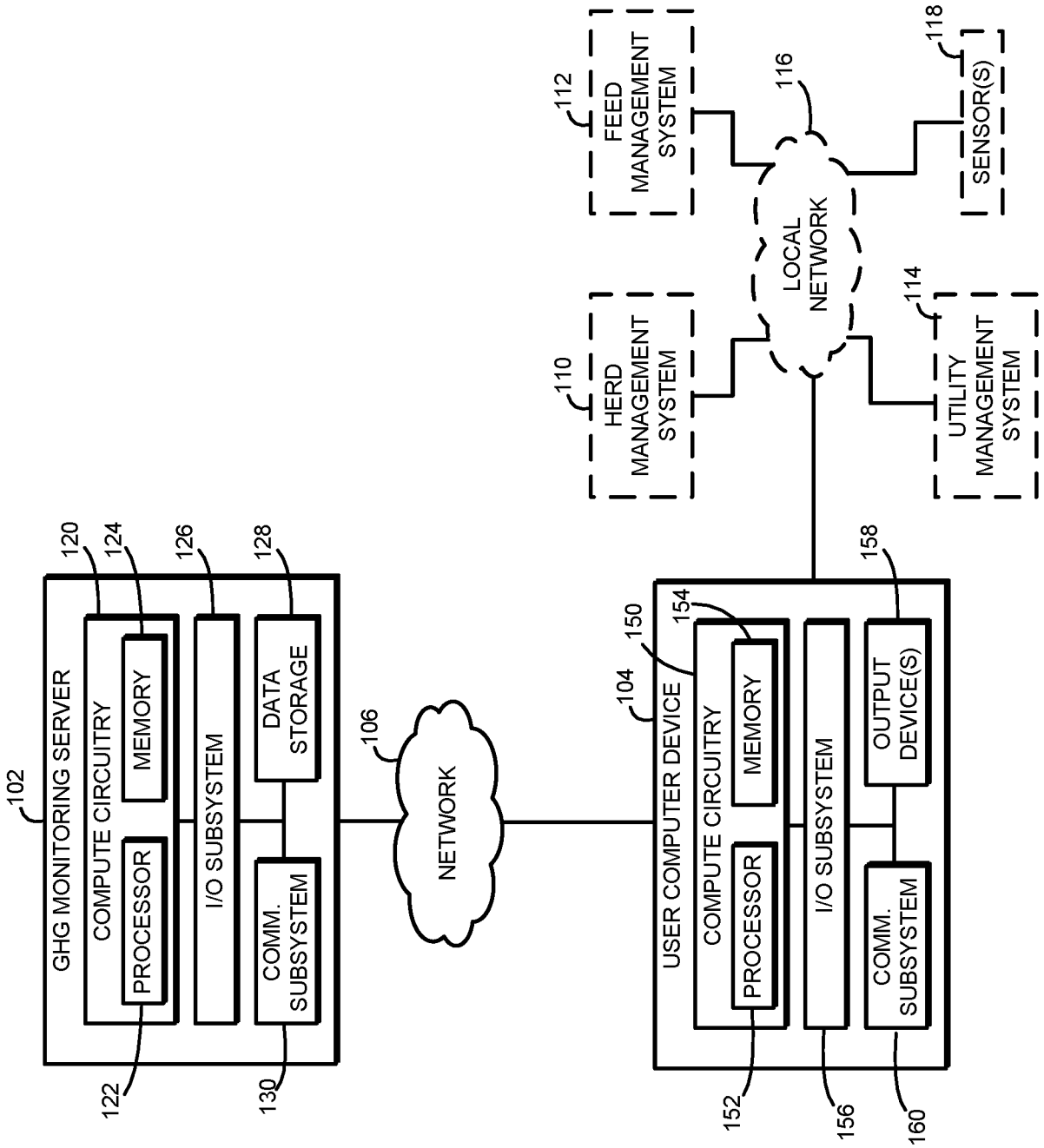


FIG. 1

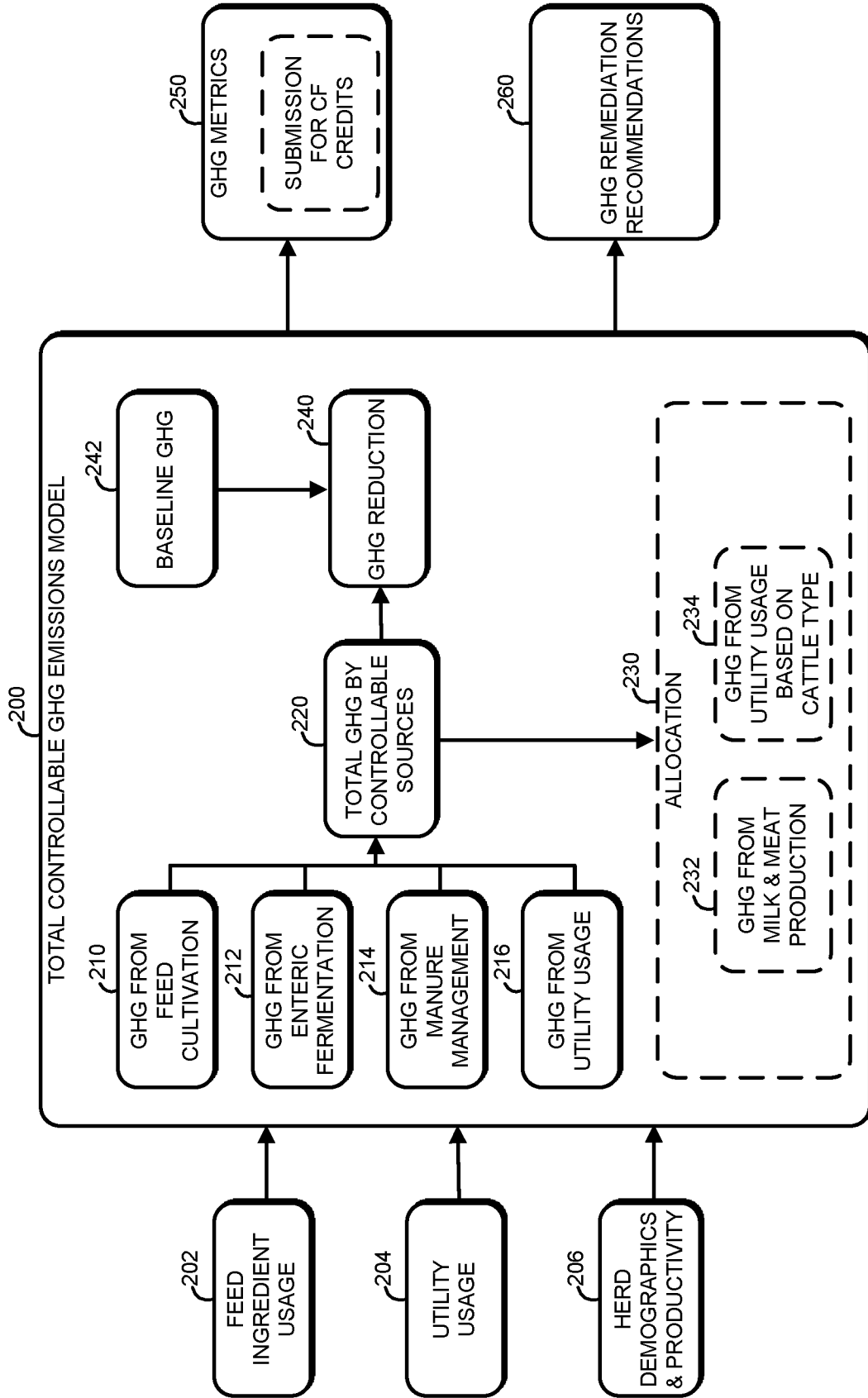


FIG. 2

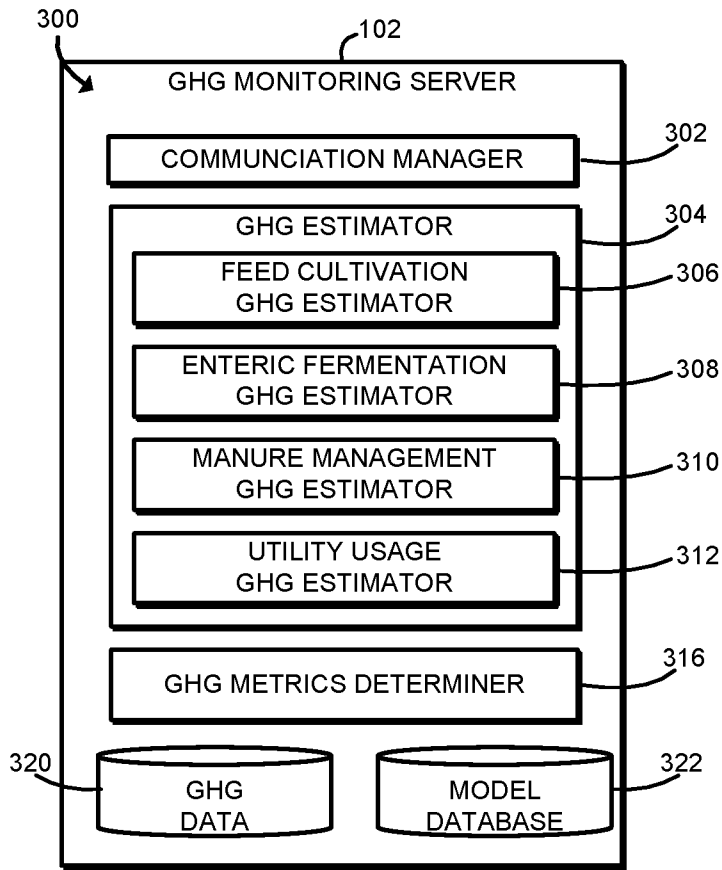


FIG. 3

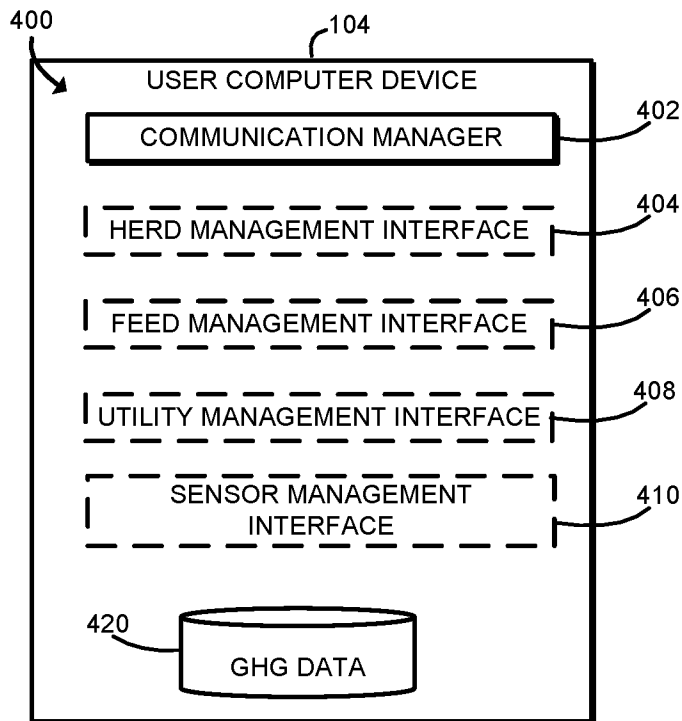


FIG. 4

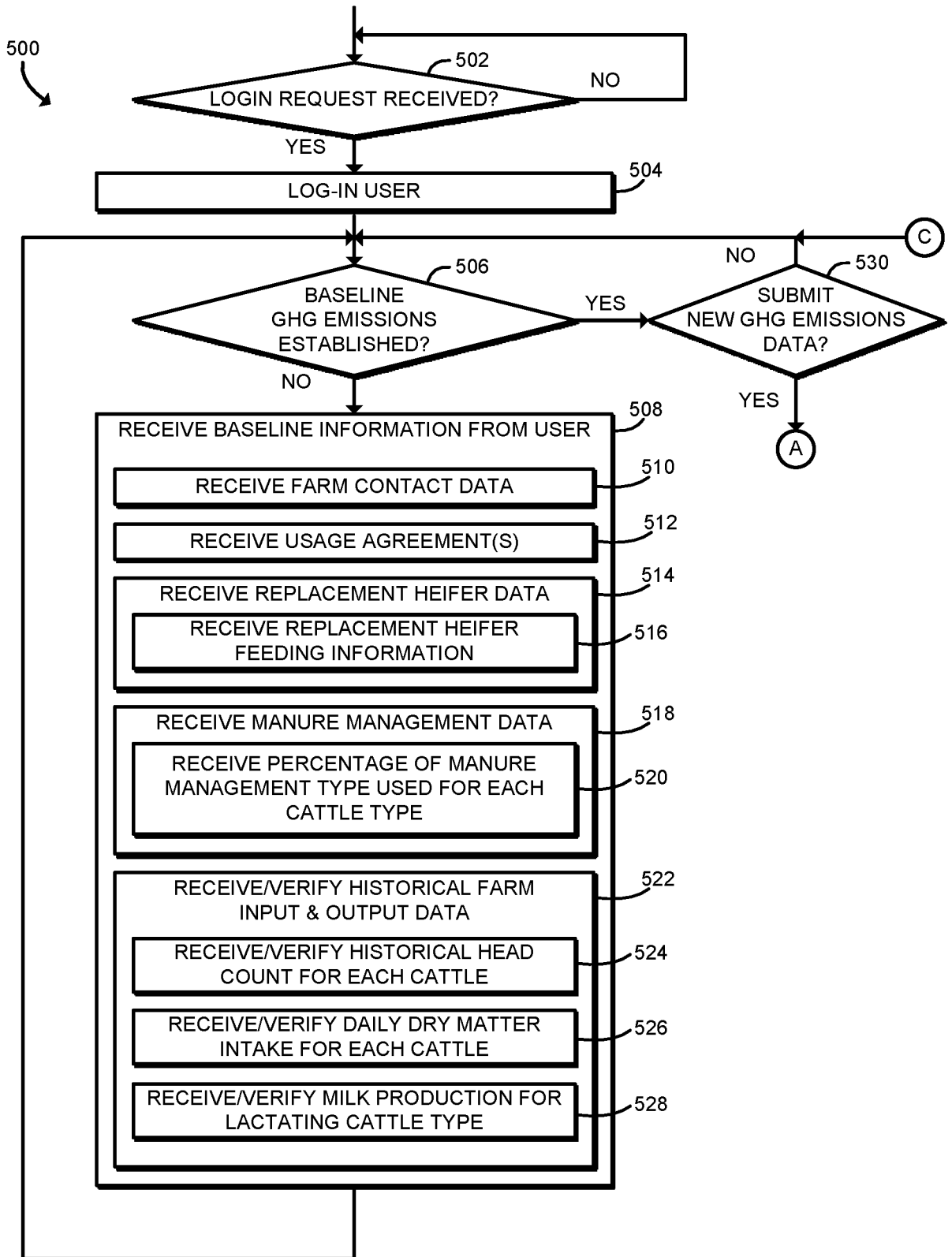


FIG. 5A

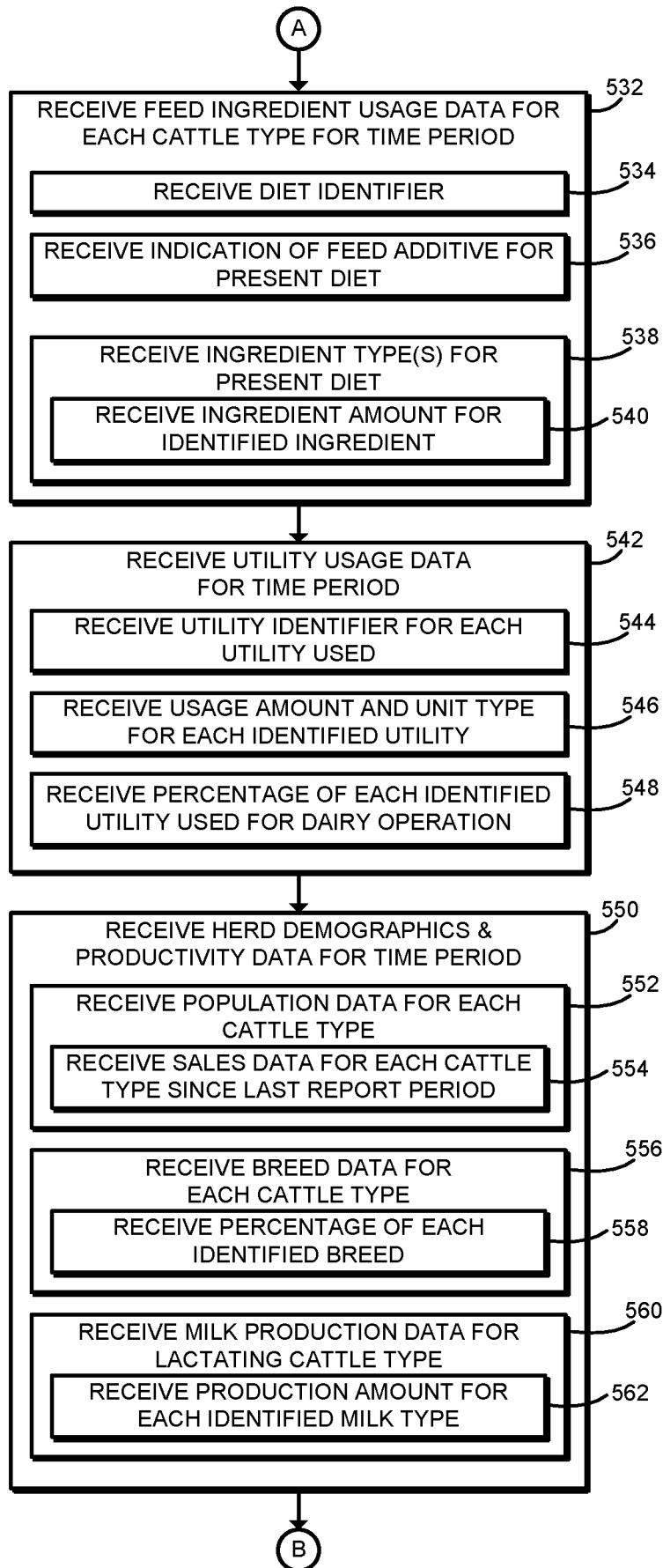


FIG. 5B

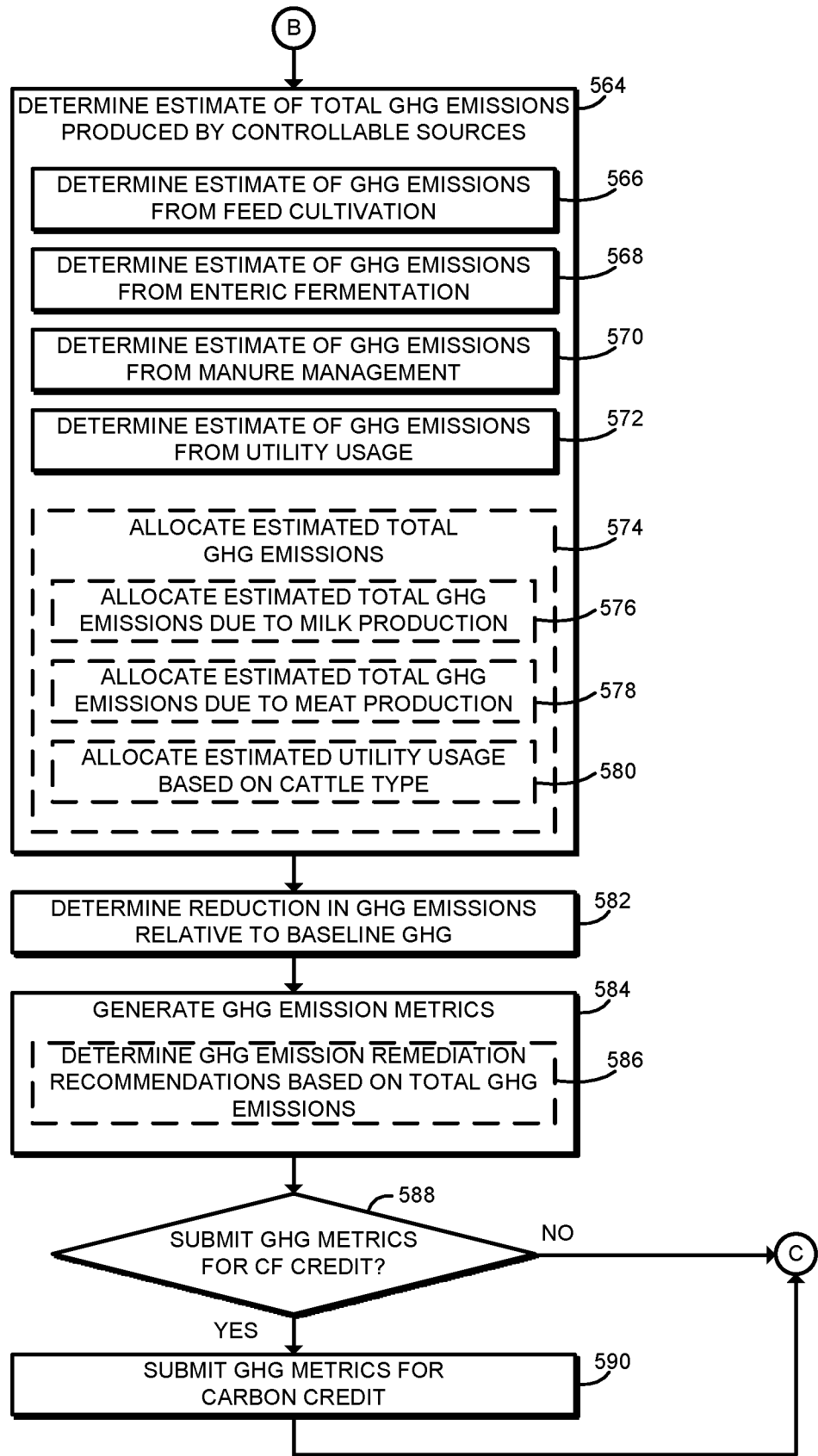


FIG. 5C

600 

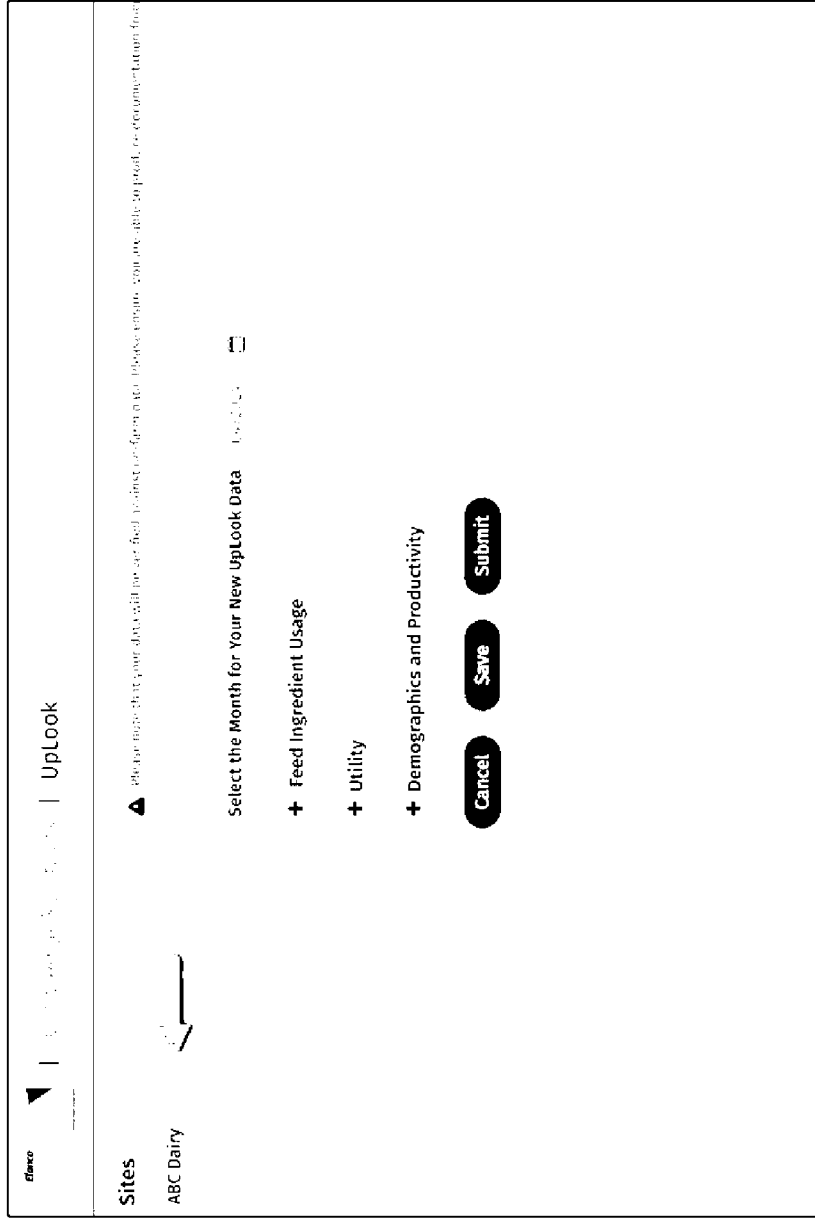


FIG. 6

700 

ABC Dairy x

Please confirm that the below data is correct and then click the button to continue. If the data is not accurate, please modify the data or send an email to abc@abc.com.

1

Contact Information [edit]

Contact Information

Address: 2500 Innovation Way N., Greenfield, Wisconsin, 54740

Phone: 317-306-5678

Manager:

[Edit Contact Information](#) **Continue**

FIG. 7

800 

ABC Dairy

Please confirm that the below data is correct and then click the button to continue. If the data is not accurate, please modify the data or send an email to [support@abc.com](#).

Replacement Heifers

Replacement Heifers

Raised on-site for the entire heifer development period

Average daily feeding rate for your milk and/or milk replacer for pre-weaned calves (quarts per calf/day)

Average proportion (%) of the milk fed to the pre-weaned that is milk replacer

Back

FIG. 8

900

ABC Dairy
x

Please confirm that the below data is correct and then click the button to continue. If the data is not accurate, please modify the data or send an email to support@abc.com.

Manure Management

Cattle Type	Management	% of Herd
Dairy Cows	Slurry Lots	100
Heifers	Uncovered Anaerobic Lagoon	100
Heifers	Slurry Lots	100
Calving	Slurry Lots	100
Calving	Advanced Digestor, Low Leachage, High Quality Cattle and Swine, Best Composts, Anaerobic Technology	90

Manure Management

Back

Continue

FIG. 9

1000 ↗

ABC Dairy

Please confirm that the below data is correct and then click the button to continue. If the data is not accurate, please send an email to abc@abc.com.

Recent Monthly Data

Month	Cattle Type	Head Count	Daily Dry Matter Intake (lb/hd/day)	Milk (lb/hd/day)
Feb. 2024	Lactating	1000	40.0	120.0
	Dry	200	20.0	0.0
	Pre-Fresh	100	15.0	0.0
	Fresh	100	15.0	0.0
Mar. 2024	Lactating	1000	40.0	120.0
	Dry	200	20.0	0.0
	Pre-Fresh	100	15.0	0.0
	Fresh	100	15.0	0.0
Apr. 2024	Lactating	1000	40.0	120.0
	Dry	200	20.0	0.0
	Pre-Fresh	100	15.0	0.0
	Fresh	100	15.0	0.0

Recent Monthly Data

9

Back
Continue

FIG. 10

1100 

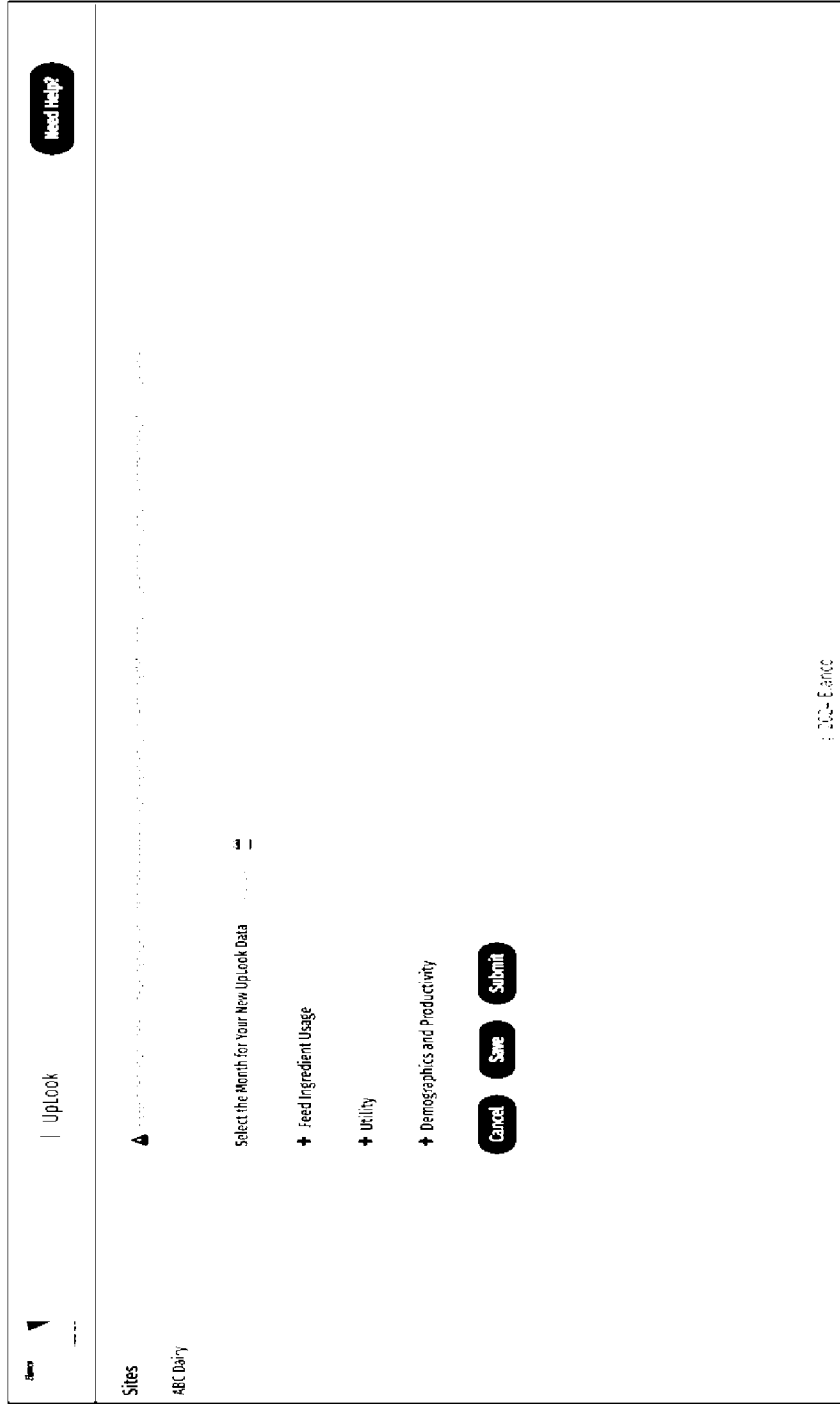


FIG. 11

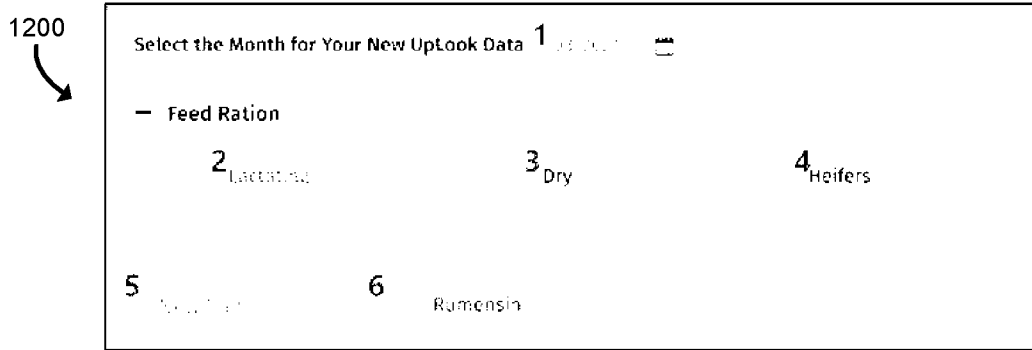


FIG. 12



FIG. 13

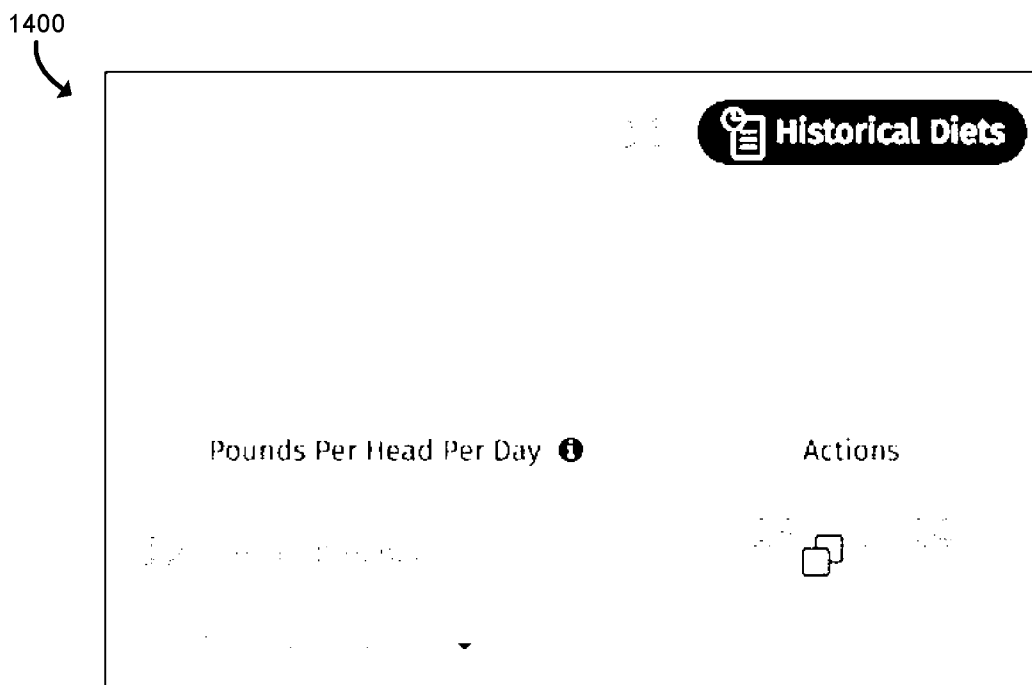


FIG. 14

1500

Utility

+ Add New



No	Utility type	Total Units	Unit type	Energy-Question	Actions
1		3	4	What percentage of this energy is used for the daily operations versus other farm operations?	 

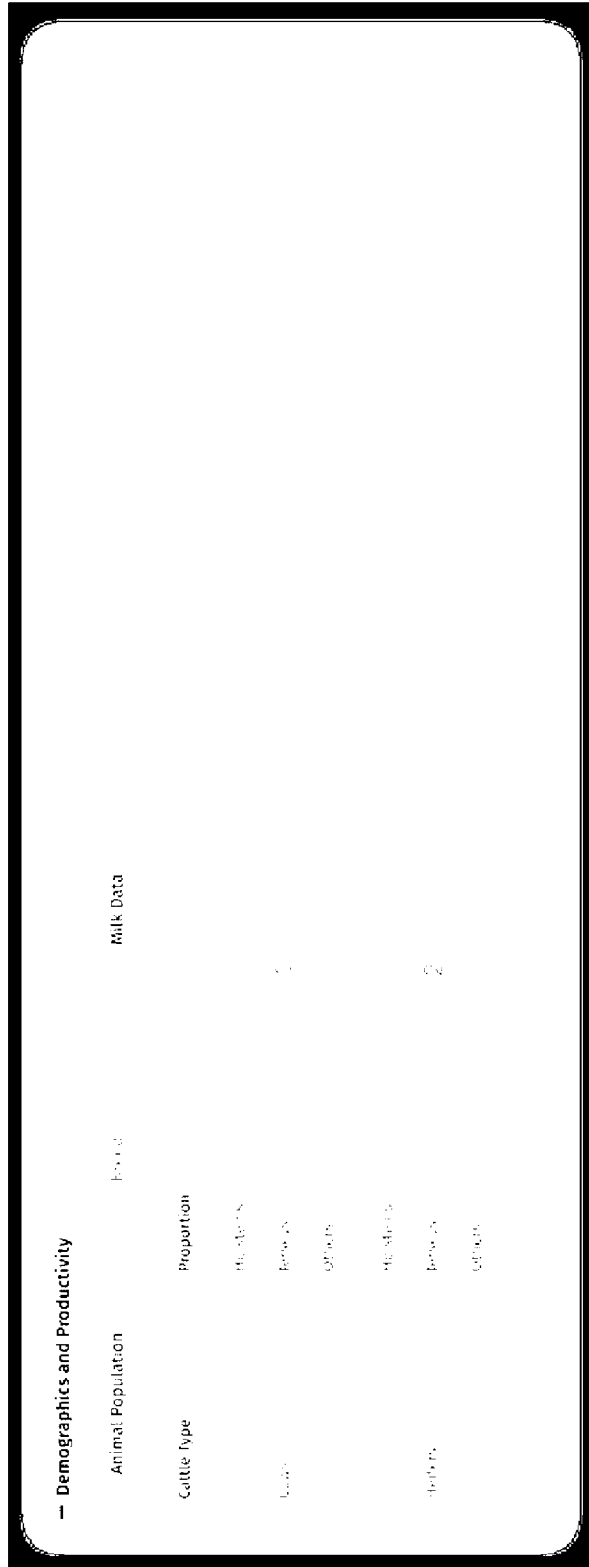
FIG. 15

1600 

- Demographics and Productivity		Breed	Milk Data
Counts			
Cattle type	Average number of cattle on site this month		
Female	3125		
Male	666		
Milk production	2763		
Sold	2		
Cattle type	Number of cattle sold this month		
Female	312		Average weight per head 1389
Milk production			
Weight			

FIG. 16

1700



— Demographics and Productivity			
Animal Population	Female	Milk Data	
Cattle Type	Proportion		
	Holsteins		
	Jerseys	1	
	Others		
	Holsteins		
	Jerseys	2	
	Others		

FIG. 17

1800 

Demographics and Productivity

Animal Population	Breed	Months	Unit Type
	Total value for this month	1	m
Milk	2875080	1	m
Meat (kg)	299627	2	
kg (kg)	238107	3	

FIG. 18

1900 

Carbon Footprint - Current Month vs. Same Month, Previous Year									
Carbon Footprint of Dairy, kg CO ₂ e									
	Current month (Jul 2023)				Previous year (Jul 2022)				kg CO ₂ e/kg FPCM
	Total for dairy	MT Per lact cow	Per kg of FPCM	Percent of total	Total for dairy	MT Per lact cow	Per kg of FPCM	Percent of total	
Enteric methane	743,839	0.32	0.4167	33.3%	726,123	0.33	0.4399	33.5%	1.4
Manure - N ₂ O	189,909	0.13	0.1064	8.5%	187,769	0.14	0.1138	8.7%	
Manure - CH ₄	509,949	0.40	0.3193	25.5%	544,556	0.40	0.3299	25.1%	1
Feed	624,148	0.44	0.3497	27.9%	605,444	0.44	0.3668	27.9%	
Fuel and electricity	108,878	0.08	0.0609	4.9%	103,328	0.08	0.0638	4.9%	0.8
Total	2,230,584	1.37	1.2529	100.0%	2,169,219	1.38	1.3142	100.0%	0.6
↳ chg from prev yr									
	3.1%	-0.8%	-4.7%						
Proportion of total by cattle type									
Lactating cows				77.3%					0.4
Dry cows				7.3%					
Replacement heifers				15.4%					0.2
Beef				0.0%					0
Proportion of total by product									
Milk				89.7%					Current month (Jul 2023)
Beef				10.3%					Previous year (Jul 2022)
									91.1%
									8.9%

FIG. 19

2000 

Carbon Footprint - Last 12 Months vs. Previous Year									
Carbon Footprint of Dairy, kg CO ₂ e									
	Last 12 months, Aug 2022 - Jul 2023			Previous year, Aug 2021 - Jul 2022			kg CO ₂ e/kg FPCM		
	Total for dairy	MT per lact cow	Per kg FPCM, of total	Total for dairy	MT per lact cow	Per kg FPCM, of total			
Enteric methane	8,923,870	6.45	0.4180	8,712,833	6.73	0.4419	33.7%		1.2
Manure - N2O	2,237,230	1.63	0.1039	2,230,317	1.74	0.1161	8.7%		1
Manure - CH ₄	6,796,720	4.91	0.3188	6,518,972	3.04	0.3306	23.2%		0.8
Feed	7,487,997	5.40	0.3503	7,229,313	5.38	0.3466	27.9%		0.6
Fuel and electricity	1,231,328	0.89	0.0579	1,168,877	0.50	0.0993	4.3%		0.6
Total	26,676,963	19.27	1.2314	25,880,454	19.99	1.3126	100.0%		
% chg from prev yr	3.1%	3.6%	-4.7%						
Proportion of total by cattle type									
Lactating cows			77.6%				76.3%		0.6
Dry cows			3.8%				5.6%		0.2
Replacement heifers			16.7%				16.2%		0
Beef			0.0%				0.0%		
Proportion of total by product									
Milk			88.8%				91.3%		
Beef			11.2%				8.7%		
* Fat and protein corrected milk									

FIG. 20

2100

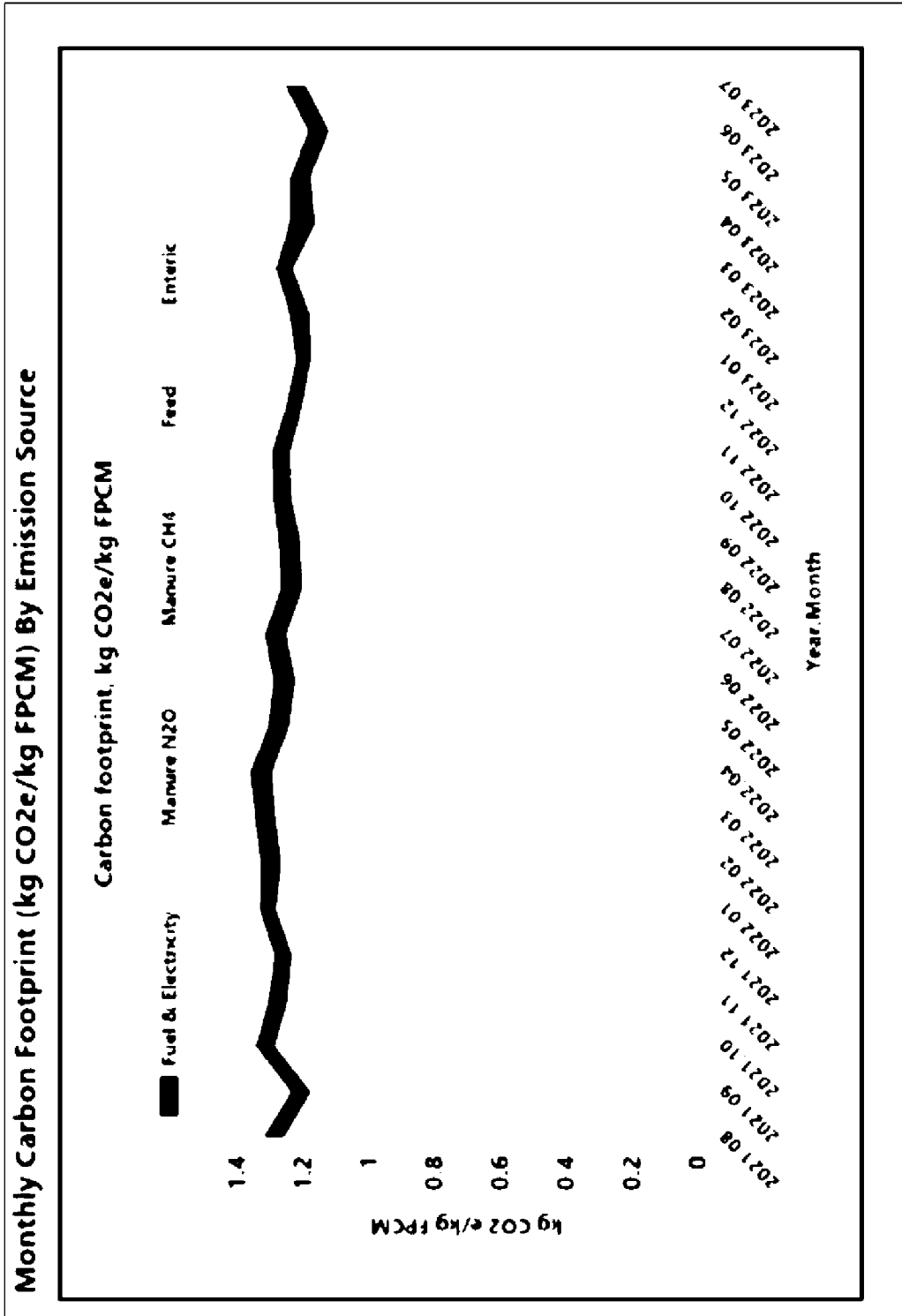


FIG. 21

2200

ANIMAL TYPE	DESCRIPTION
LACTATING COWS	COWS PRODUCING MILK, INCLUDING COWS UNDER VETERINARY TREATMENT IN THE HOSPITAL PEN
DRY COWS	DRY COWS
REPLACEMENT HEIFERS	FEMALE ANIMALS BEING RAISED TO ENTER THE LACTATING HERD, FURTHER CLASSIFIED INTO TWO AGE CATEGORIES: 0 TO 12 MONTHS OF AGE AND 12.1 MONTHS OF AGE
BEEF ANIMALS	BEEF ANIMALS

FIG. 22

2300

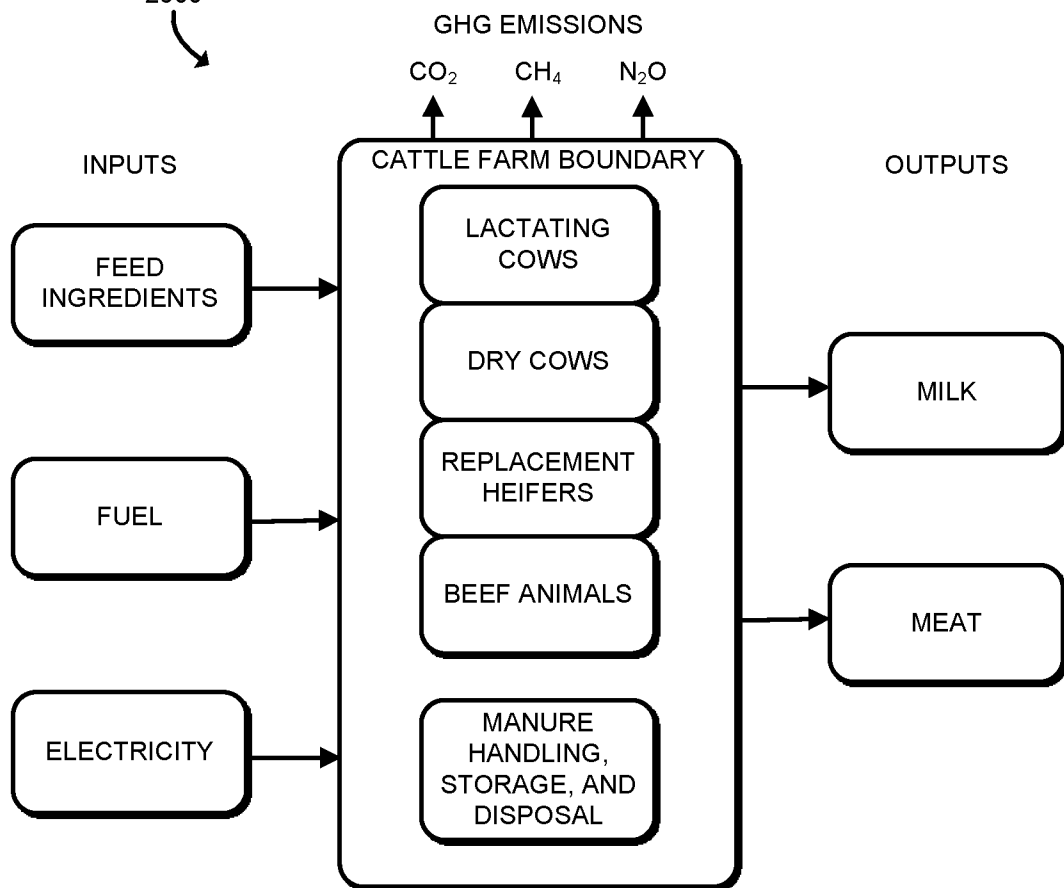


FIG. 23

2400


SOURCE	CHG	INCLUDED/ EXCLUDED	JUSTIFICATION
1. FEED CULTIVATION	CO ₂ N ₂ O	INCLUDED	EMISSIONS FROM THE PRODUCTION, HARVESTING, PROCESSING, AND TRANSPORTATION OF CATTLE FEED
2. ENTERIC FERMENTATION	CH ₄	INCLUDED	EMISSIONS FROM ENTERIC FERMENTATION IN CATTLE
3. MANURE MANAGEMENT	CH ₄ N ₂ O	INCLUDED	EMISSIONS FROM THE MANAGEMENT OF MANURE
4. FUEL AND ELECTRICITY USE	CO ₂ N ₂ O CH ₄	INCLUDED	EMISSIONS FROM EQUIPMENT USING GASOLINE OR DIESEL ON THE DAIRY, STATIONARY FUEL USE ON THE DAIRY, AND ELECTRICITY USE ON THE DAIRY
5. DIRECT LAND USE	CO ₂	EXCLUDED	DAIRIES WITH LAND USE CHANGES RESULTING IN AN INCREASE $\geq 1\%$ OF ANNUAL FARM EMISSION ARE EXCLUDED, AND LAND USE CHANGE RESULTING IN $< 1\%$ OF ANNUAL FARM EMISSIONS IS CONSIDERED DE MINIMIS
6. BEDDING	CO ₂ N ₂ O CH ₄	EXCLUDED	EMISSIONS FROM THE USE OF DIFFERENT BEDDING MATERIALS ARE CONSIDERED DE MINIMIS
7. WASTE PROCESSING	CO ₂ N ₂ O CH ₄	EXCLUDED	EMISSIONS FROM THE MANAGEMENT OF DEAD ANIMALS ARE CONSIDERED DE MINIMIS

FIG. 24

2500 

INGREDIENT	DM (%)	EF (kg CO ₂ e kg ⁻¹ DM)	CP (%)	NDF (%)	GE (MJ/kg)	DE (%)
ALFALFA MEAL	90.749	0.17	19.513	42.853	16.887	61.917
ALMOND HULLS	88.201	0.20	5.250	33.005	16.404	62.081
AMMONIUM CHLORIDE	100.000	3.30	163.600	0.000	2.089	0.000
AMMONIUM PHOSPHATE (DIBASIC)	100.000	3.30	115.900	0.000	9.508	0.000
AMMONIUM PHOSPHATE (MONOBASIC)	100.000	3.30	70.90	0.000	6.401	0.000
AMMONIUM SULFATE	100.000	3.30	134.100	0.000	11.266	0.000
APPLE POMACE OR BYPRODUCT	18.234	0.2	6.419	45.725	17.549	54.430
BAKERY BYPRODUCT	90.129	0.46	12.832	12.664	19.302	77.882
BAKERY BYPRODUCT, BREAD WASTE	67.441	0.46	14.900	6.345	18.855	81.129
BAKERY BYPRODUCT, CEREAL	91.137	0.46	9.195	7.202	17.756	80.967

FIG. 25

2600 

FUEL TYPE (UNITS)	EIA VALUE (kg CO ₂ e /fuel unit)	ROTZ ET AL (kg CO ₂ e /fuel unit)	TOTAL VALUE
NATURAL GAS (MM BUT)	52.91	18.25	71.16
DIESEL FUEL (GALLON)	10.19	1.97	12.16
UNLEADED E-10 (GALLON)	8.1	1.97	10.07
PROPANE (GALLON)	5.75	1.908	7.73

FIG. 26

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2024/045734

A. CLASSIFICATION OF SUBJECT MATTER

IPC - INV. A23K 50/10; A01K 29/00; A23K 10/00; A23K 10/30; G06N 20/00; G06Q 10/06; G06Q 50/02 (2024.01)

ADD.

CPC - INV. Y02P 90/95; A01K 29/005; A23K 10/00; A23K 10/30; A23K 50/10; G06N 20/00; G06Q 10/063; G06Q 50/02; Y02P 60/20; Y02P 60/22; Y02P 60/50; Y02P 90/84; Y02P 90/845

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)

See Search History document

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

See Search History document

Electronic database consulted during the international search (name of database and, where practicable, search terms used)

See Search History document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 8,307,785 B2 (ZIMMERMAN, P et al.) 13 November 2012; abstract; figure 9; column 5, lines 33-37; column 20, lines 37-42; column 21, line 64 to column 33, line 58	1-78
A	US 9,980,995 B2 (COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION) 29 May 2018; column 1, line 63 to column 2, line 23; column 2, lines 42-45	1-78
A	US 2016/0324188 A1 (ALLTECH, INC.) 10 November 2016; paragraphs [0115], [0116], [0148], [0149], [0154]; claims 1, 3, 4	1-78
A	KR 20230118019 A (HWAN, P et al.) 10 August 2023; See machine translation: abstract; claim 1; paragraphs [0008], [0016], [0059], [0061]	1-78
A	US 2022/0015390 A1 (LOCUS IP COMPANY LLC) 20 January 2022; abstract; paragraph [0017]; claim 1	1-78
A	WO 2022/145792 A1 (KYUNGPOOK NATIONAL UNIVERSITY) 07 July 2022; English machine translation document: abstract; paragraphs [48], [68]	1-78

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents:

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“D” document cited by the applicant in the international application

“E” earlier application or patent but published on or after the international filing date

“L” document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

“O” document referring to an oral disclosure, use, exhibition or other means

“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

“X” document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

14 November 2024 (14.11.2024)

Date of mailing of the international search report

DEC 16 2024

Name and mailing address of the ISA/

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P.O. Box 1450, Alexandria, Virginia 22313-1450

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Authorized officer

Shane Thomas

Telephone No. PCT Helpdesk: 571-272-4300