US012386638B2

(12) **United States Patent**
Schulze et al.

(10) **Patent No.: US 12,386,638 B2**
(45) **Date of Patent: Aug. 12, 2025**

(54) **SYSTEM AND METHOD FOR DYNAMIC DISPLAY OF AIRCRAFT EMISSIONS DATA**

(71) Applicant: **The Boeing Company**, Arlington, VA (US)

(72) Inventors: **Jonas Schulze**, Frankfurt (DE); **Hilna Sahle**, Darmstadt (DE); **Anna-Lisa Mautes**, Darmstadt (DE); **Daniel Artic**, Biebesheim (DE); **Michael Gottscheck**, Frankfurt (DE); **Rahul Ashok**, Singapore (SG); **Neil Titchener**, Jackson, NH (US); **Nicholas Applegate**, Long Beach, CA (US); **Hubert Wong**, Huntington Beach, CA (US); **Nadine Akari**, Lynnwood, WA (US); **Lisa Liu**, Paramus, NJ (US); **David Raymond**, Reston, VA (US); **Brian Yutko**, Somerville, MA (US)

(73) Assignee: **The Boeing Company**, Arlington, VA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 249 days.

(21) Appl. No.: **18/352,947**

(22) Filed: **Jul. 14, 2023**

(65) **Prior Publication Data**

US 2024/0086208 A1 Mar. 14, 2024

Related U.S. Application Data

(60) Provisional application No. 63/501,945, filed on May 12, 2023, provisional application No. 63/382,001,
(Continued)

(51) **Int. Cl.**
G06F 9/451 (2018.01)

(52) **U.S. Cl.**
CPC ***G06F 9/451*** (2018.02)

(58) **Field of Classification Search**
CPC G06F 9/451
See application file for complete search history.

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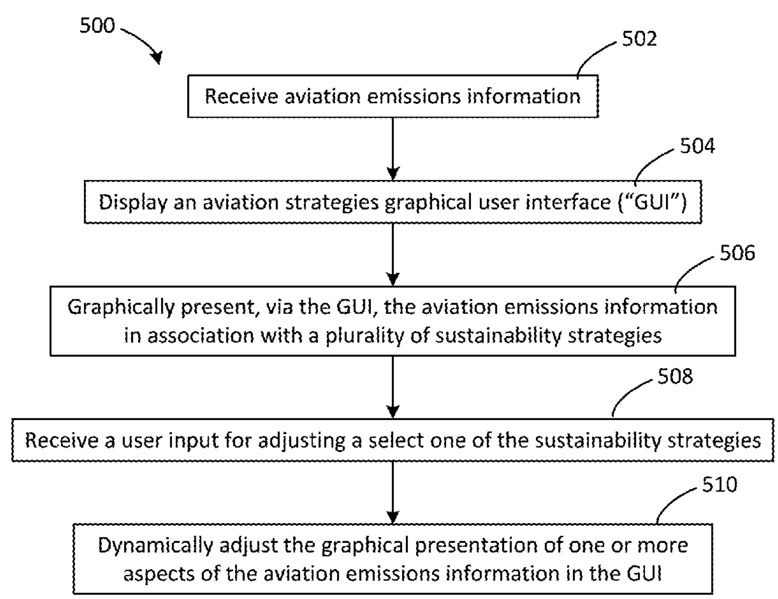
Primary Examiner — Tadesse Hailu
(74) *Attorney, Agent, or Firm* — Alleman Hall & Tuttle LLP

(57) **ABSTRACT**

Systems and methods are provided for dynamically modeling and depicting overall emissions of the aviation industry and changes thereto when taking into account, for example, traffic growth and introduction of sustainability strategies, such as new and/or improved technologies, an increase in operational efficiency, and carbon offsets. Using the dynamic tool described herein, users can define scenarios on how to reduce emissions through the introduction of different sustainability strategies, both statically and over time, analyze the impact of those strategies on emissions, and understand the dependencies between select strategies.

20 Claims, 107 Drawing Sheets
(106 of 107 Drawing Sheet(s) Filed in Color)



Related U.S. Application Data

filed on Nov. 2, 2022, provisional application No. 63/368,774, filed on Jul. 18, 2022.

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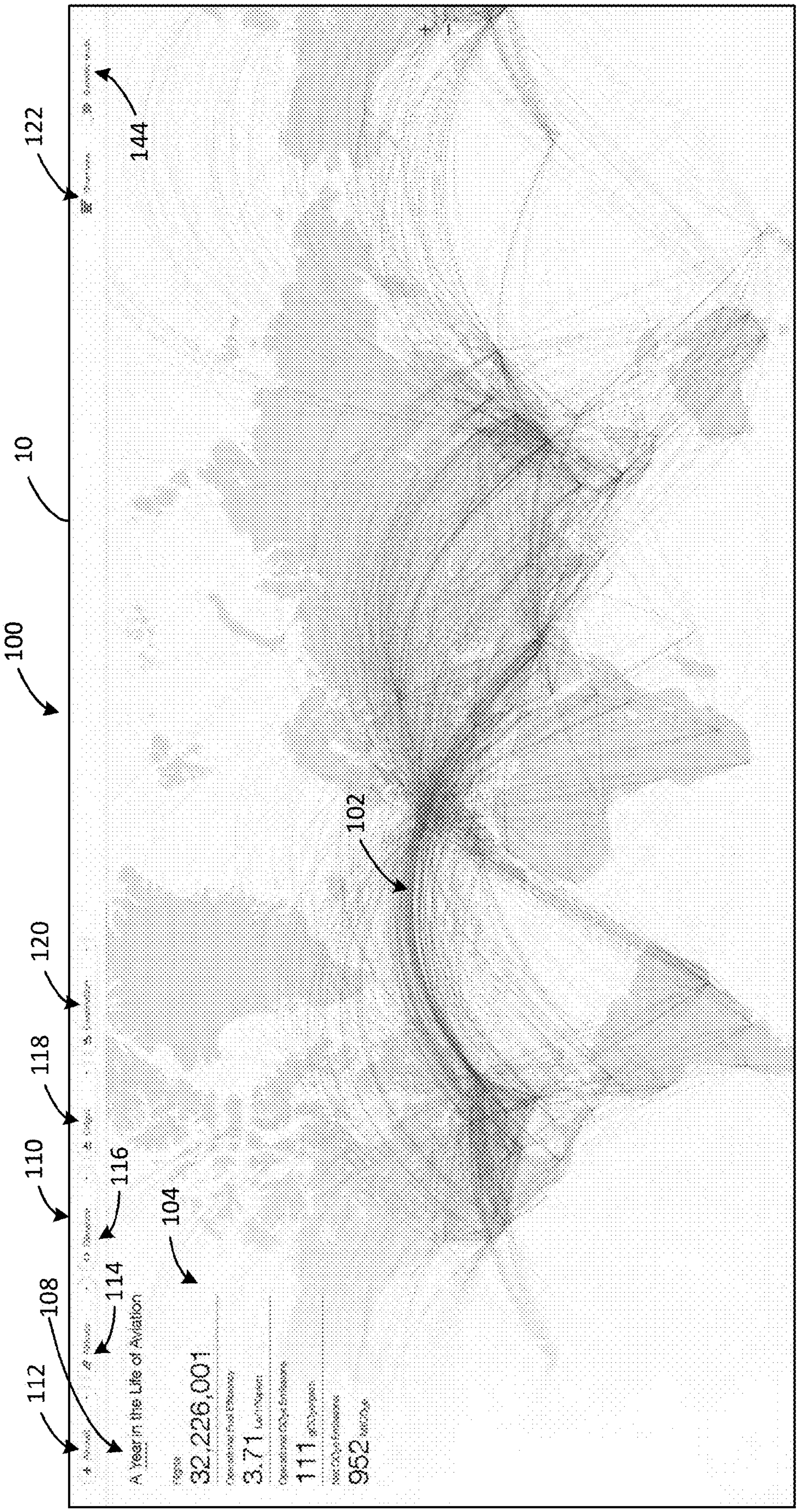

10
100
102
104
108
110
112
114
116
118
120
122
144
A Year in the Life of Aviation
32,226,001
3.71
111
952

FIG. 1

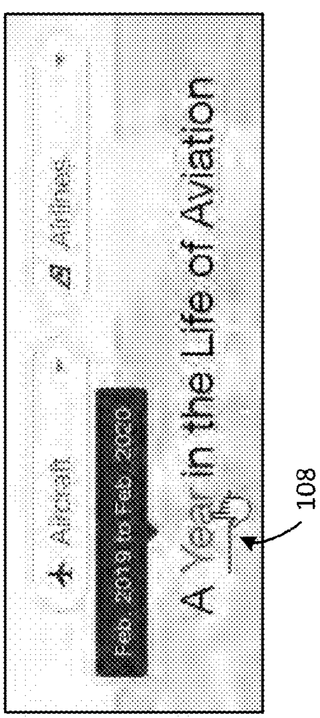


FIG. 2A

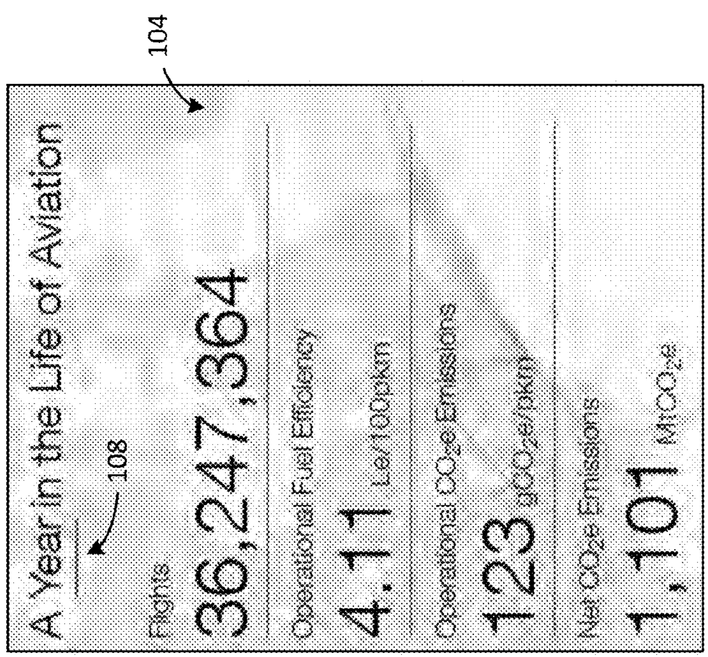


FIG. 2B

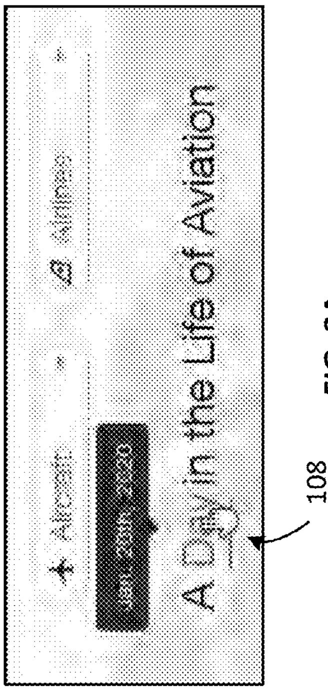


FIG. 3A

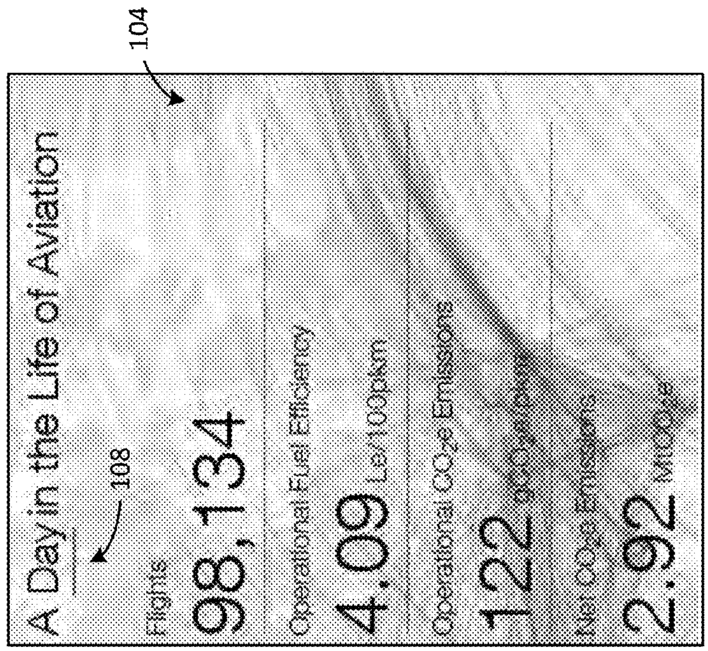


FIG. 3B

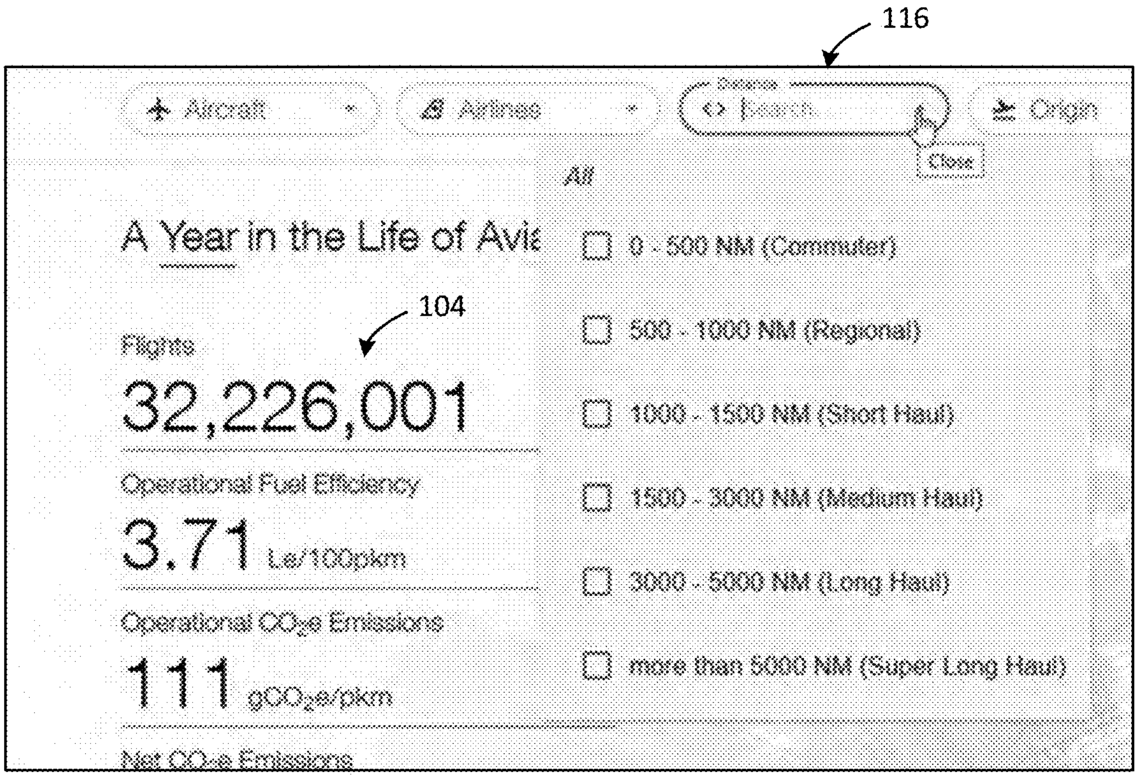

116
Aircraft
Airlines
Distance
Search
Origin
Close
All
A Year in the Life of Avi
0 - 500 NM (Commuter)
500 - 1000 NM (Regional)
1000 - 1500 NM (Short Haul)
1500 - 3000 NM (Medium Haul)
3000 - 5000 NM (Long Haul)
more than 5000 NM (Super Long Haul)
104
Flights
32,226,001
Operational Fuel Efficiency
3.71 Le/100pkm
Operational CO2e Emissions
111 gCO2e/pkm
Net CO2e Emissions

FIG. 4

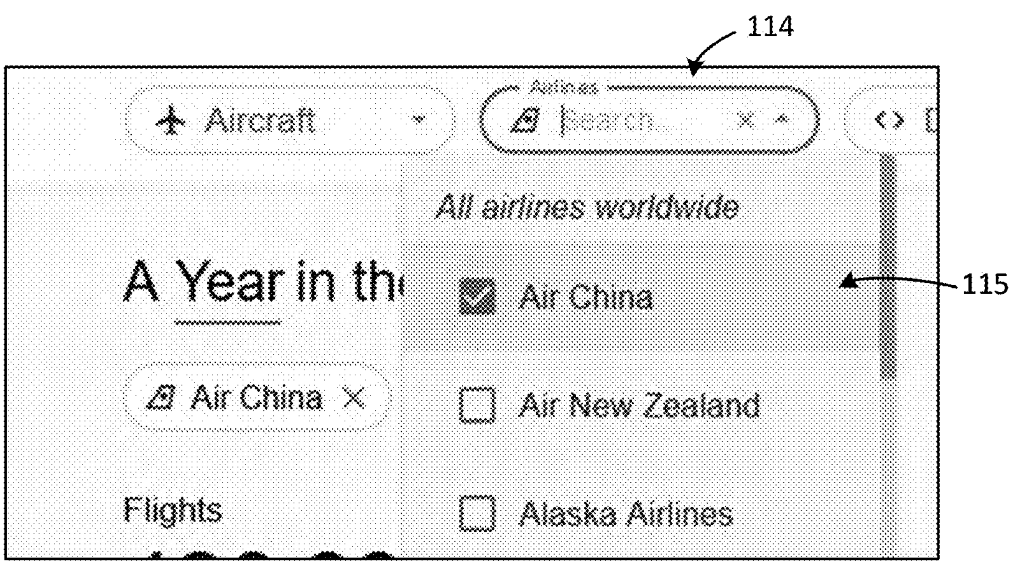

114
Aircraft
Airlines
Search...
All airlines worldwide
A Year in th
Air China
115
Air China
Air New Zealand
Flights
Alaska Airlines

FIG. 5

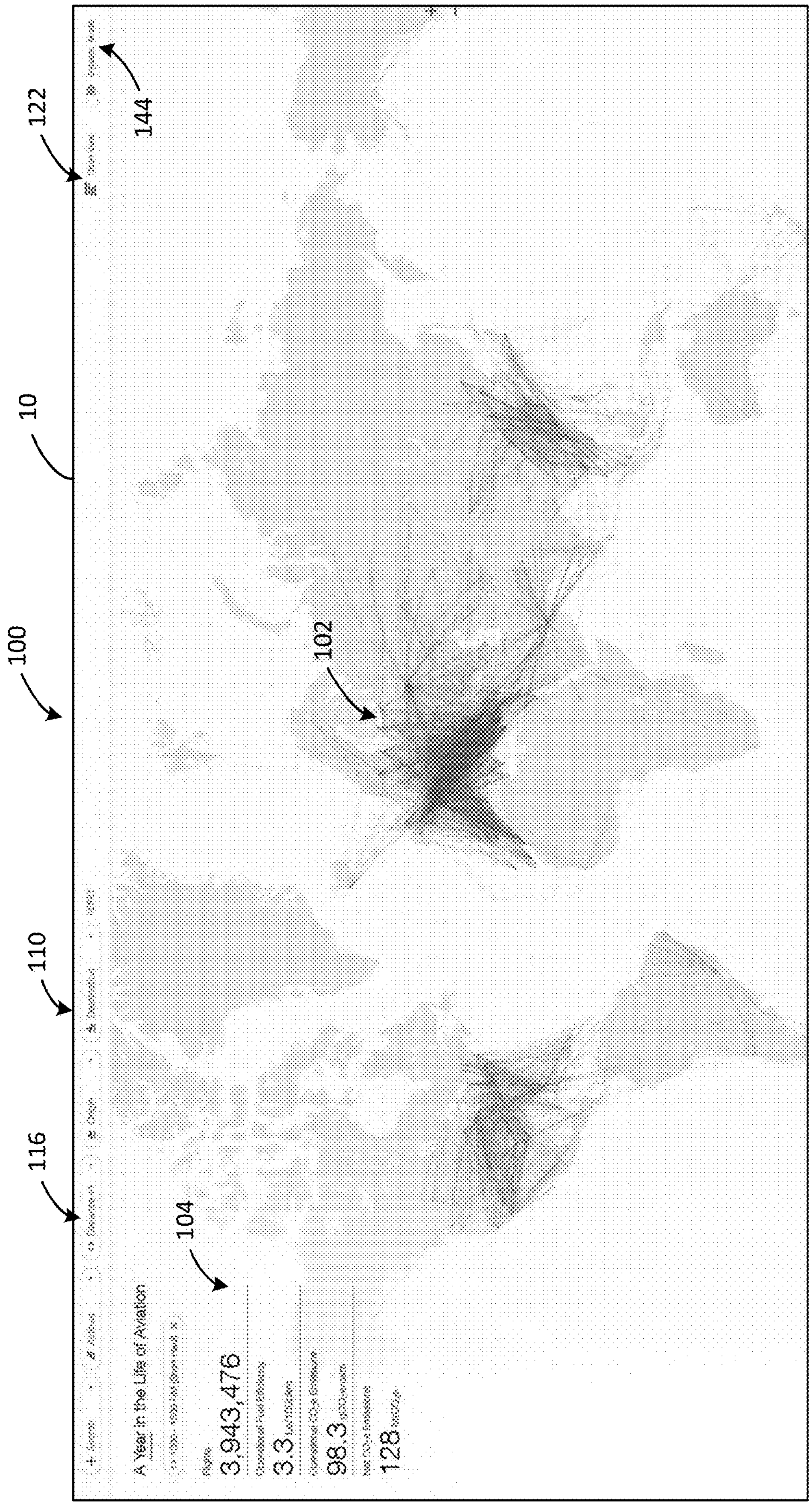

122
144
10
100
102
110
116
104
A Year in the Life of Aviation
3,943,476
3.3
98.3
128

FIG. 6

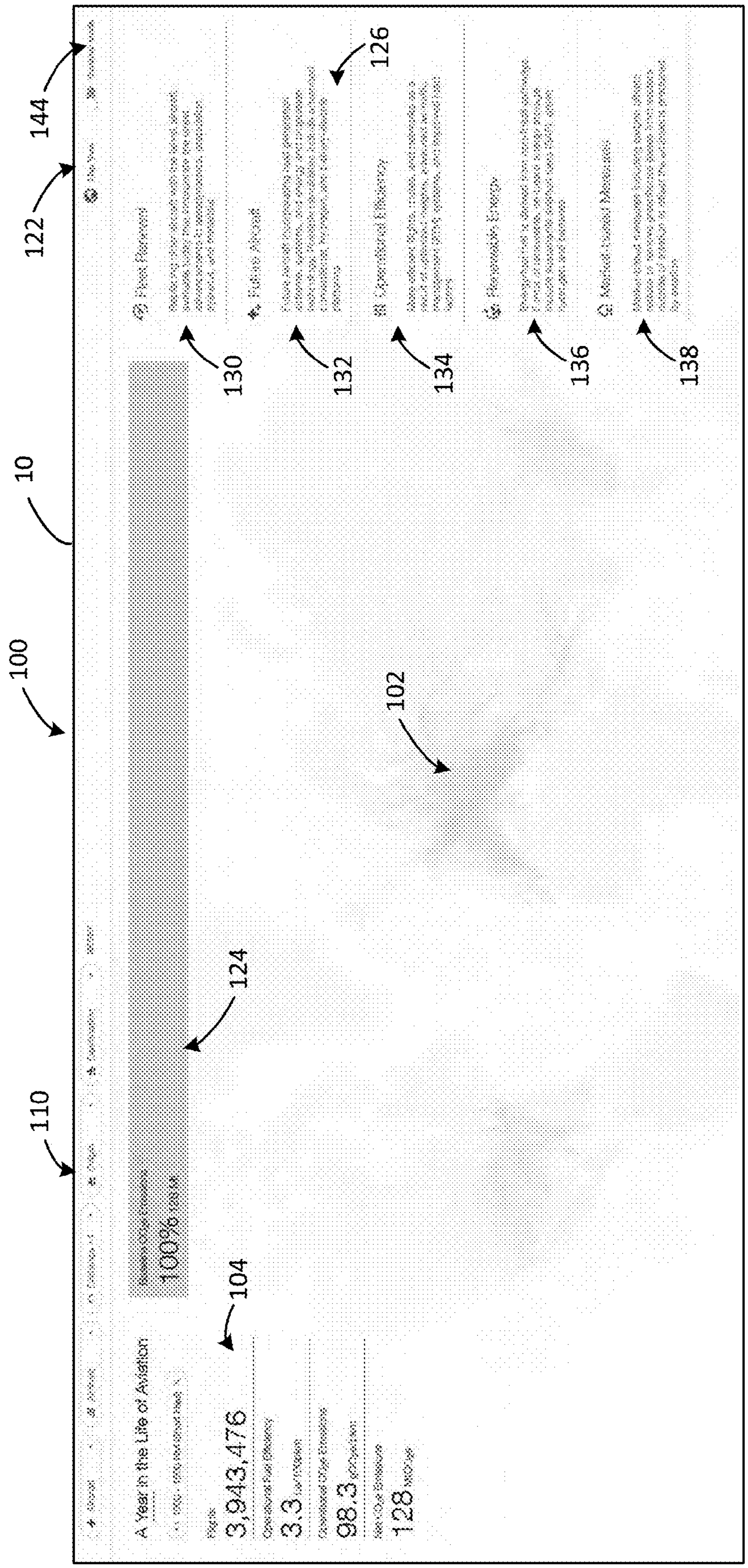

10
100
102
104
110
122
124
126
130
132
134
136
138
144
A Year in the Life of Aviation
3,943,476
3.3
98.3
128
100%

FIG. 7

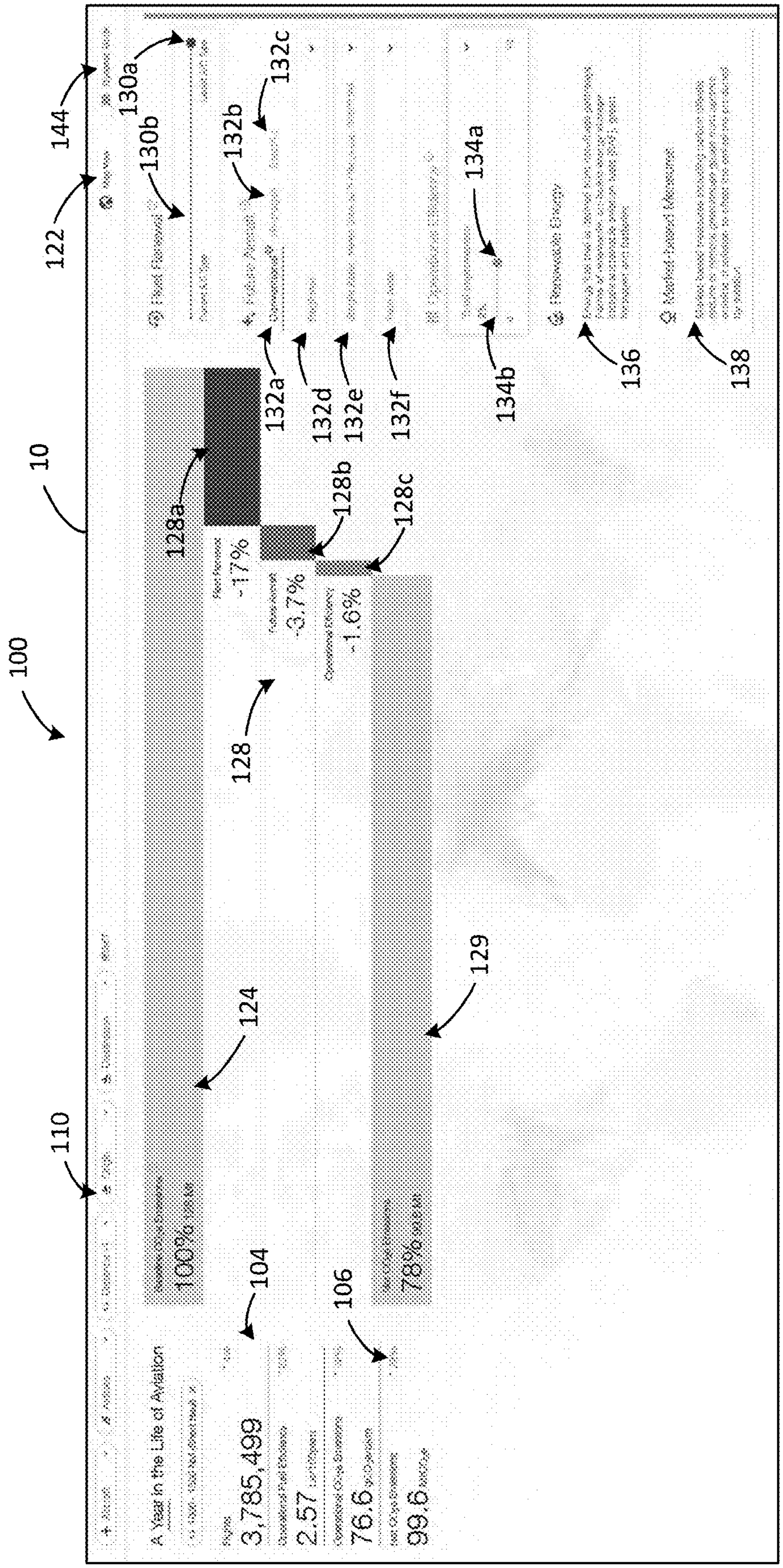

100
10
122
144
130a
130b
132a
132b
132c
132d
132e
132f
134a
134b
136
138
128
128a
128b
128c
129
124
110
104
106
A Year in the Life of Aviation
3,785,499
2.57
76.6
99.6
100%
78%
-17%
-3.7%
-1.6%

FIG. 8

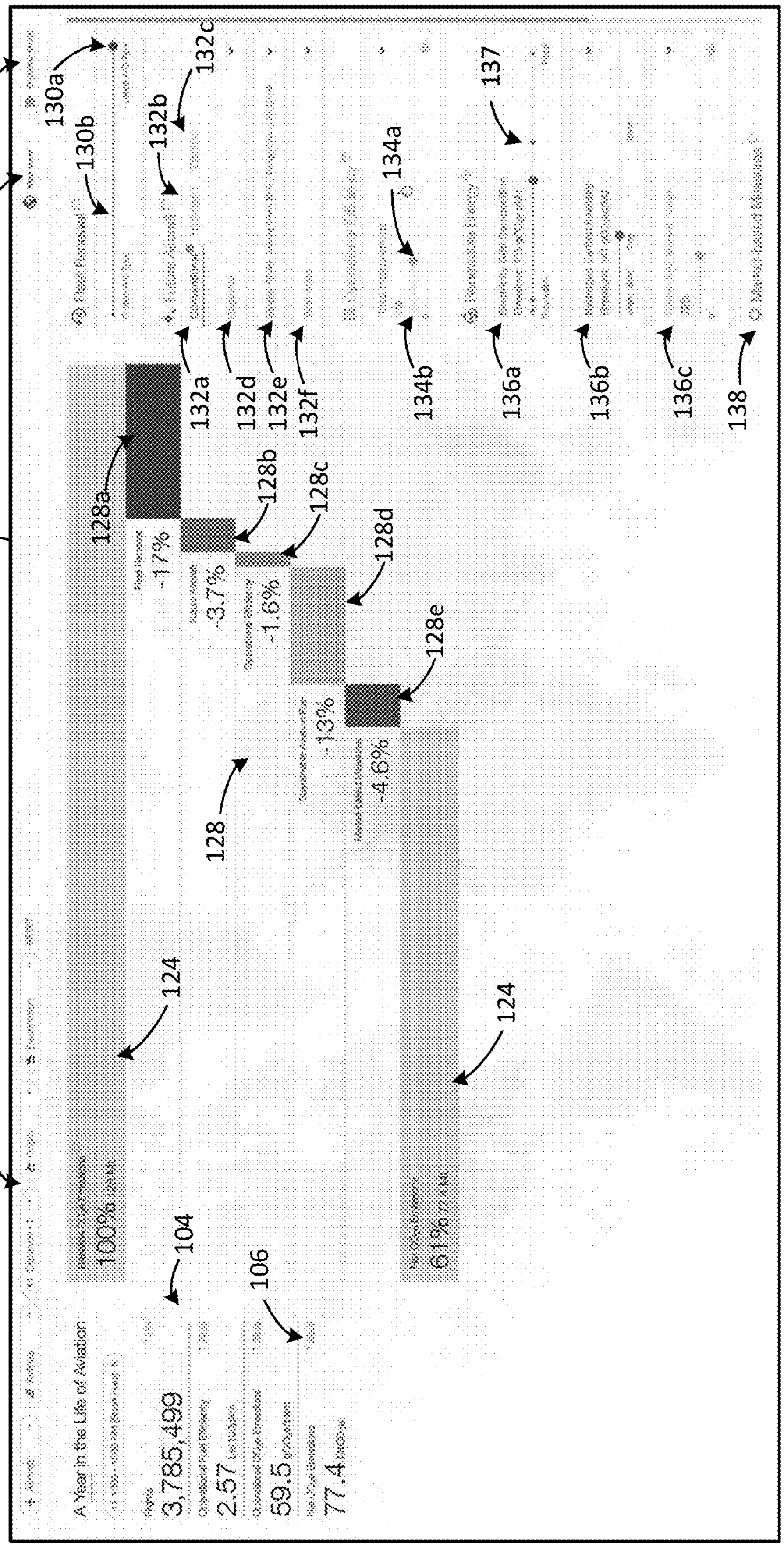

100
10
110
122
144
130a
130b
132a
132b
132c
132d
132e
132f
134a
134b
136a
136b
136c
137
138
128
128a
128b
128c
128d
128e
124
124
104
106
A Year in the Life of Aviation
3,785,499
2.57
59.5
77.4
100%
61%
-17%
-3.7%
-1.6%
-13%
-4.6%

FIG. 9A

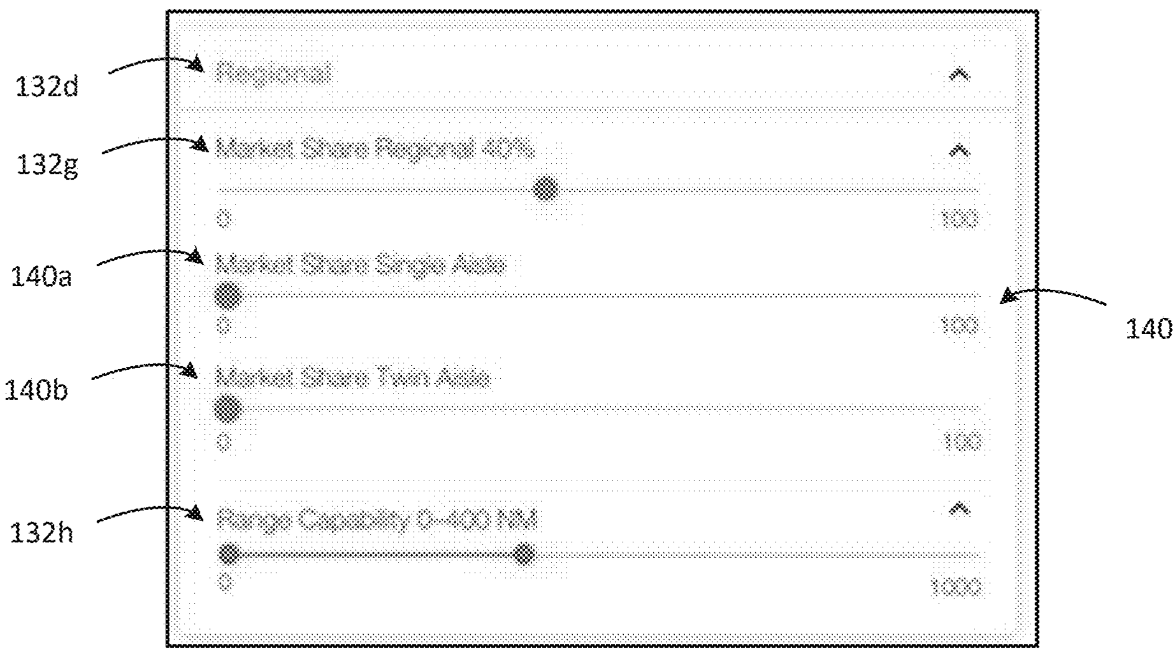

132d
Regional
132g
Market Share Regional 40%
0
100
140a
Market Share Single Aisle
0
100
140
140b
Market Share Twin Aisle
0
100
132h
Range Capability 0-400 NM
0
1000

FIG. 9B

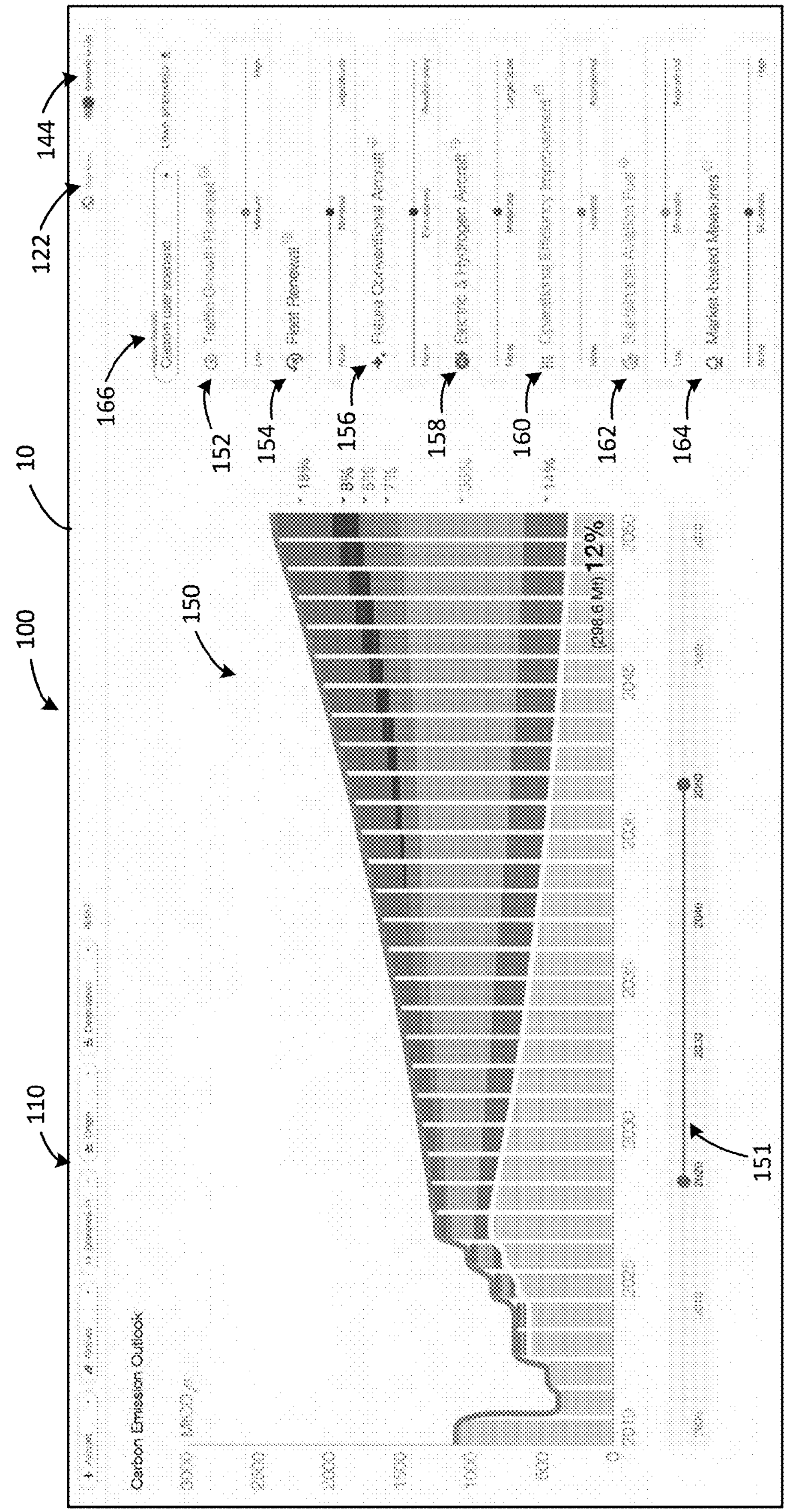

100
10
110
122
144
166
150
151
152
154
156
158
160
162
164
Carbon Emission Outlook
12%

FIG. 10

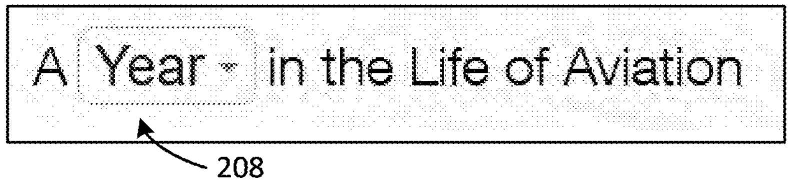


FIG. 11A

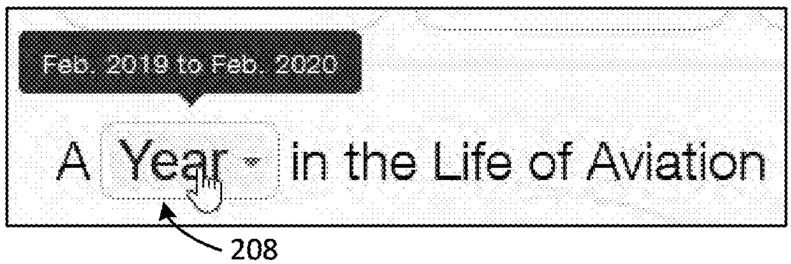


FIG. 11B

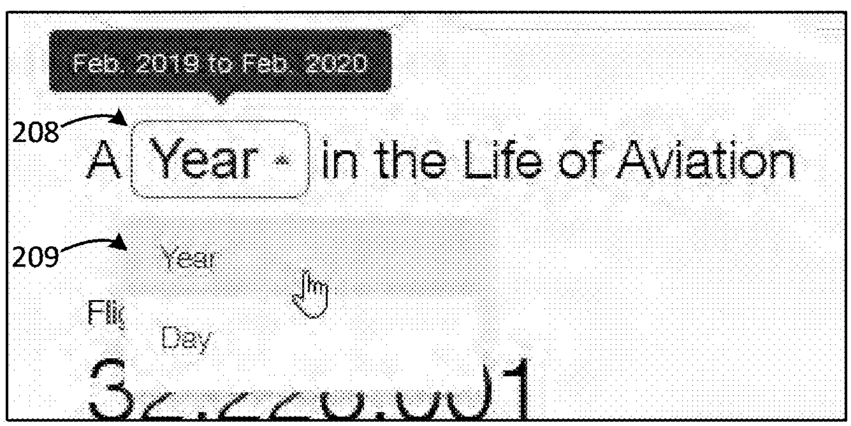


FIG. 11C

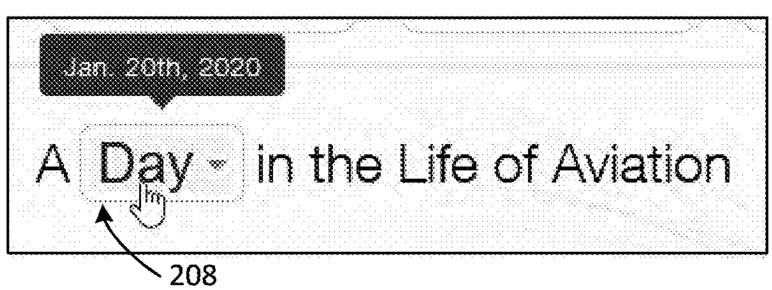


FIG. 11D

FIG. 12A

FIG. 12B

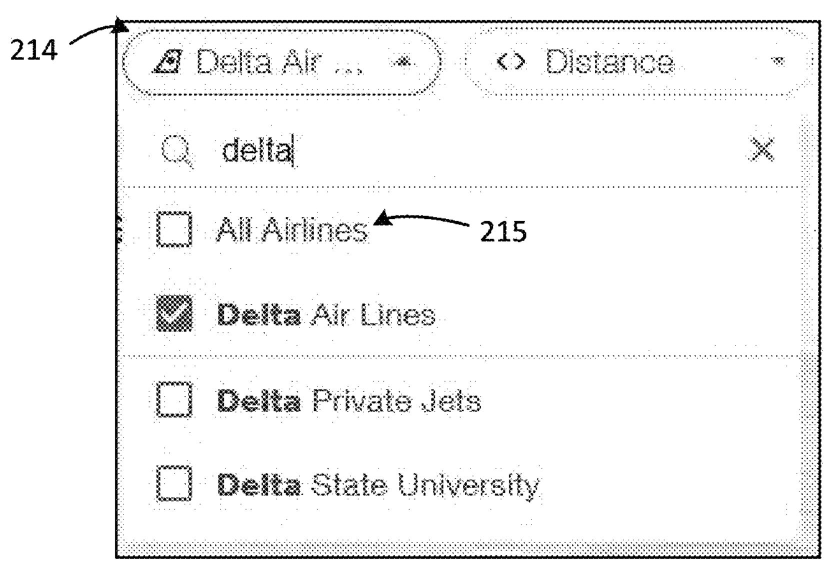


FIG. 12C

FIG. 12D

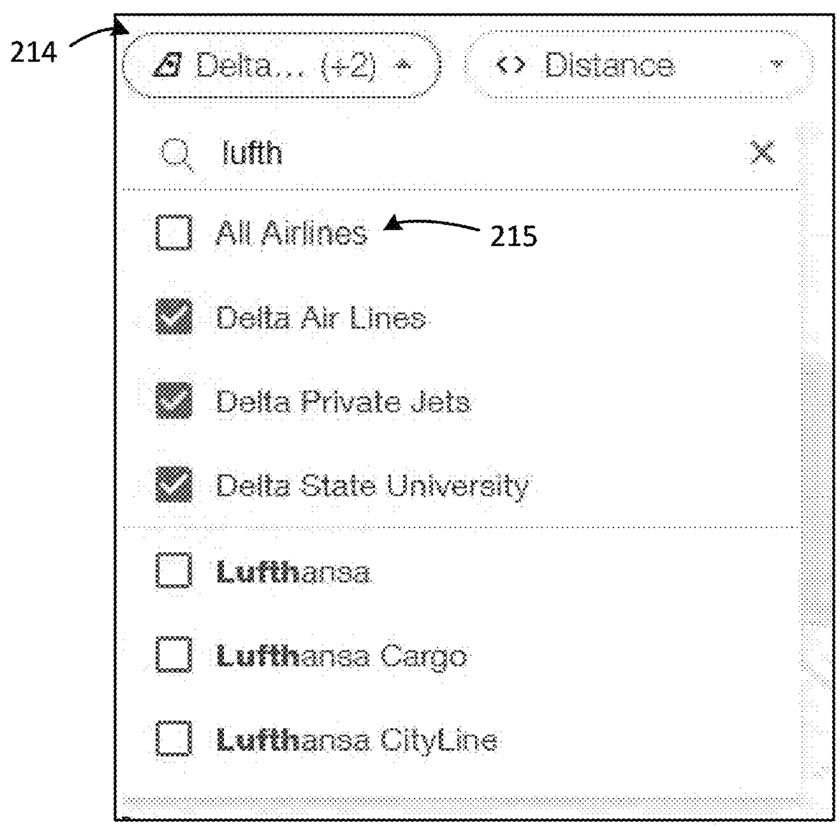


FIG. 12E

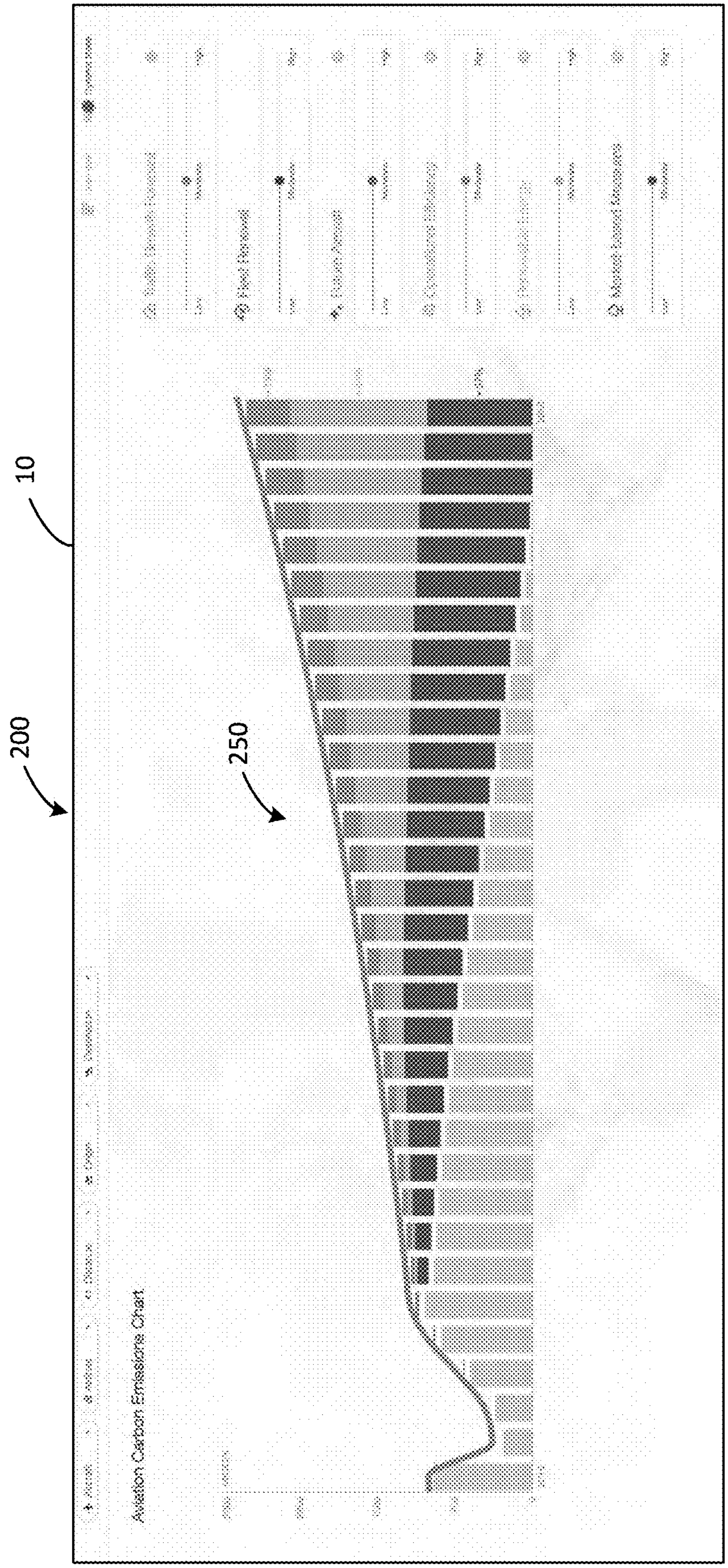
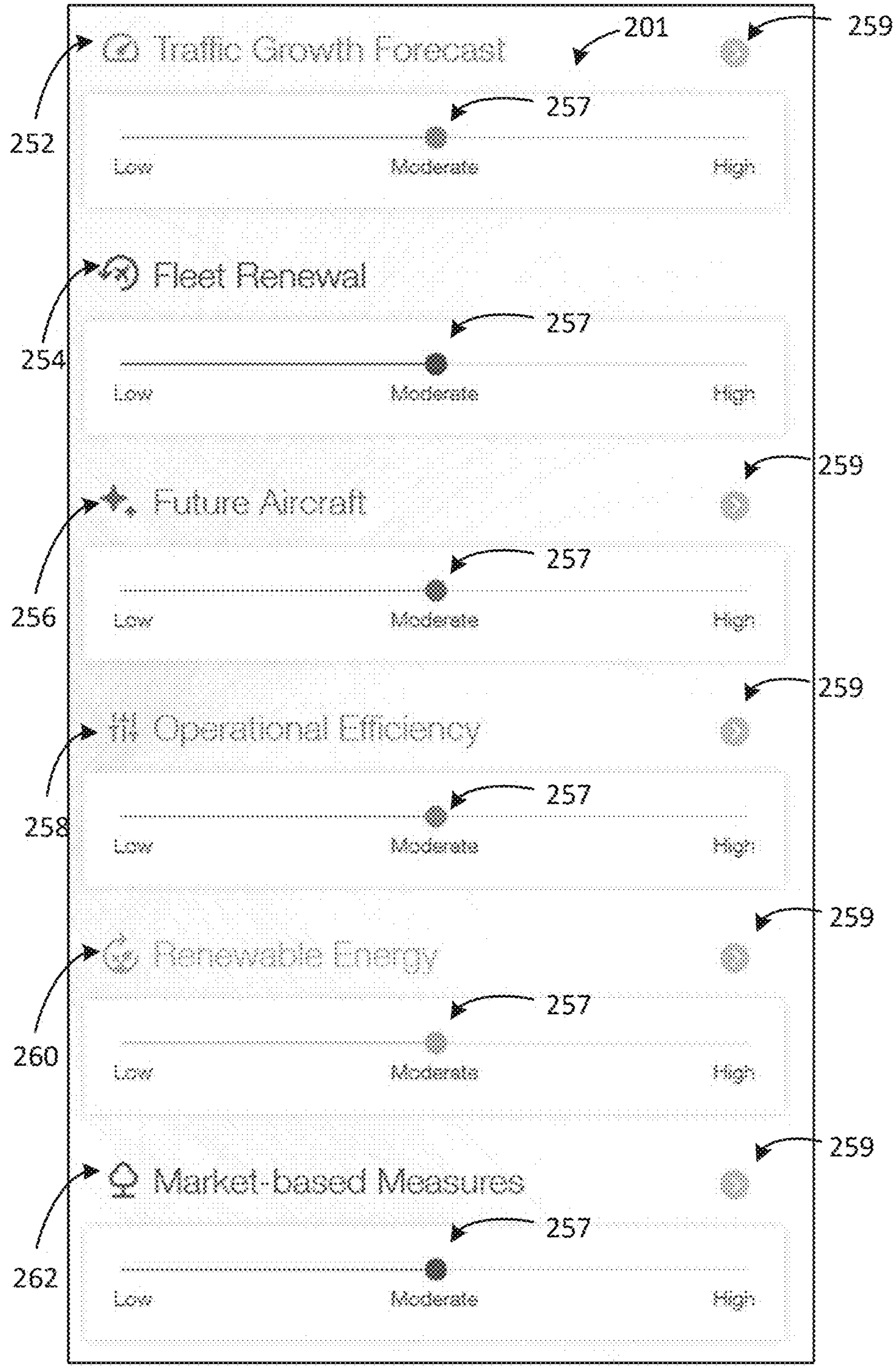


FIG. 13A



201
259
252
Traffic Growth Forecast
257
Low
Moderate
High
254
Fleet Renewal
257
Low
Moderate
High
259
256
Future Aircraft
257
Low
Moderate
High
259
258
Operational Efficiency
257
Low
Moderate
High
259
260
Renewable Energy
257
Low
Moderate
High
259
262
Market-based Measures
257
Low
Moderate
High

FIG. 13B

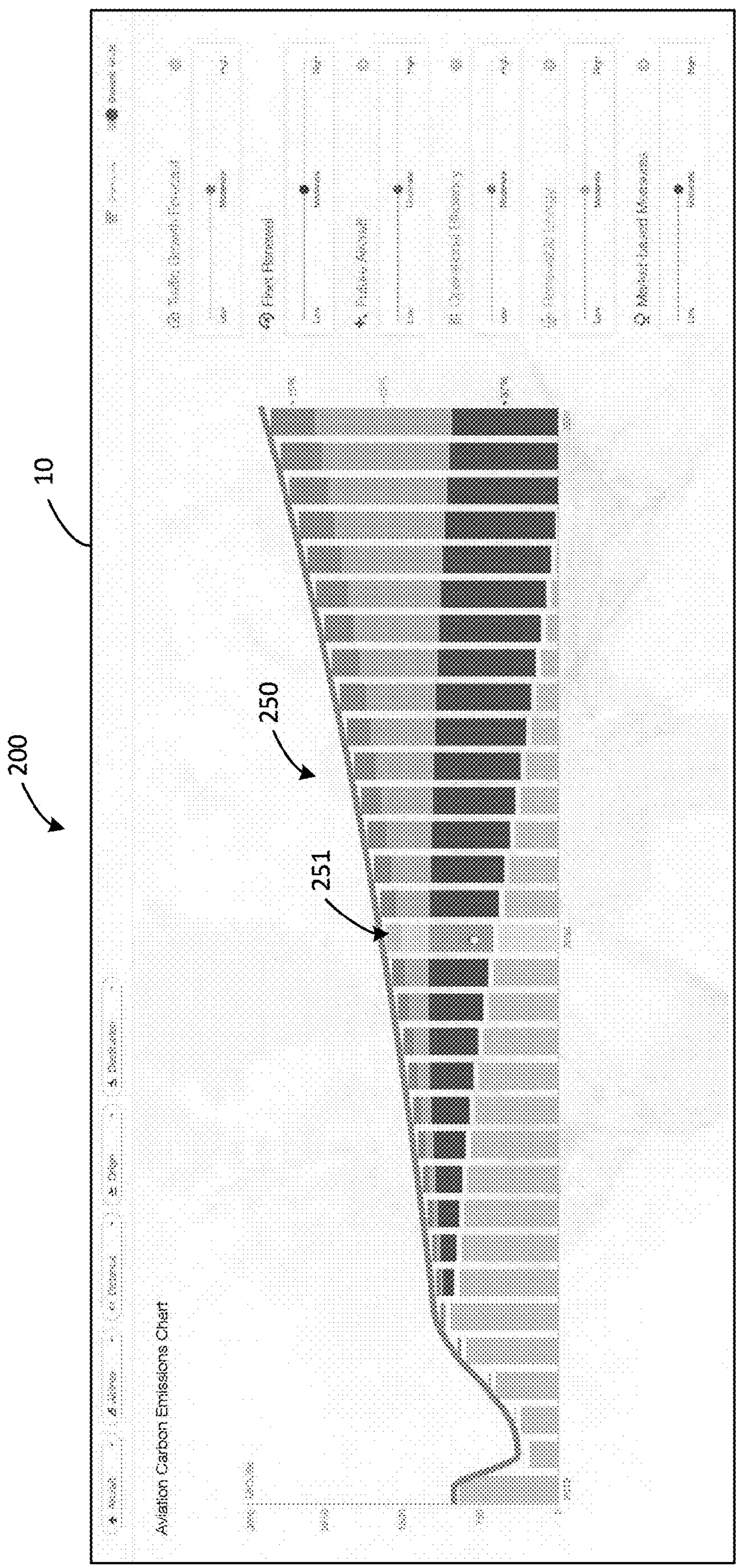


FIG. 14A

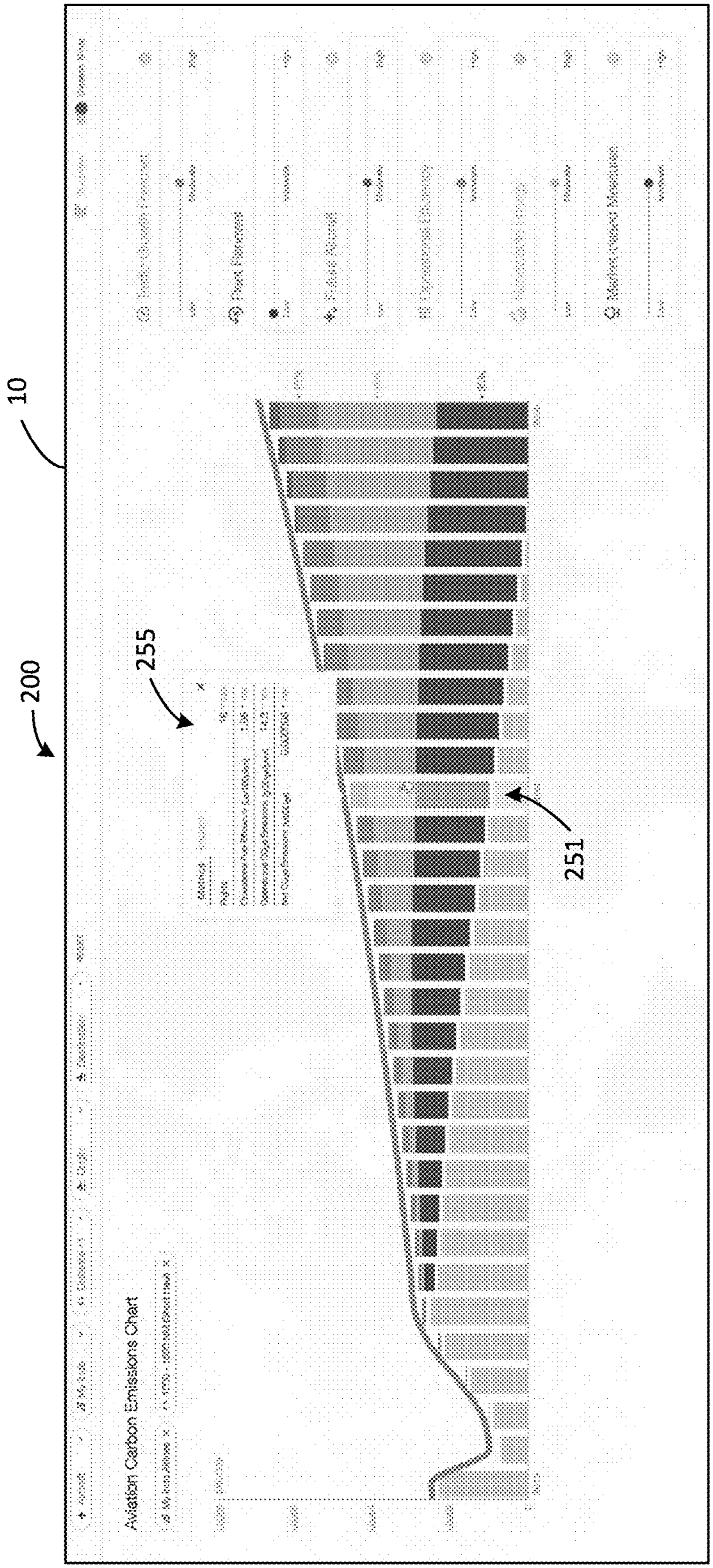


FIG. 14B

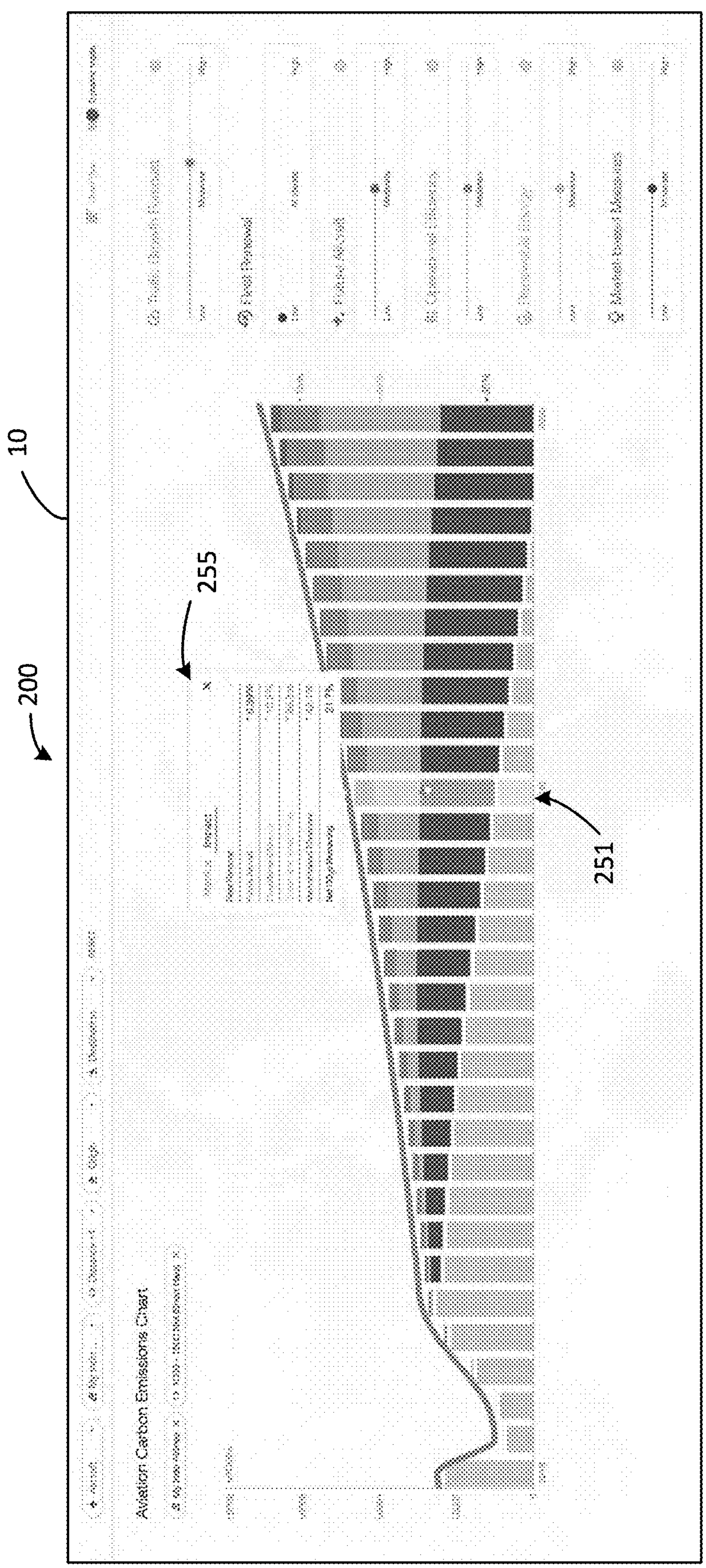


FIG. 14C

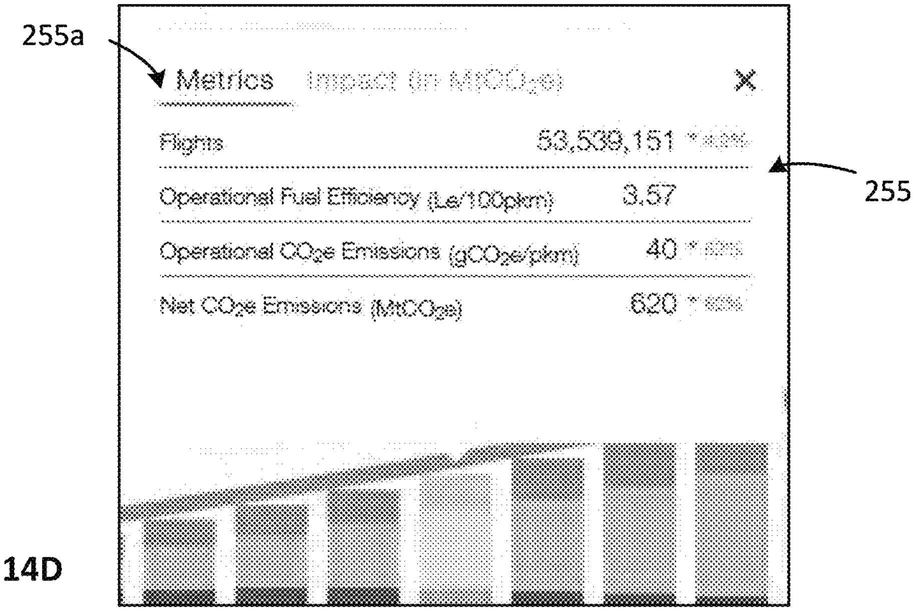


FIG. 14D

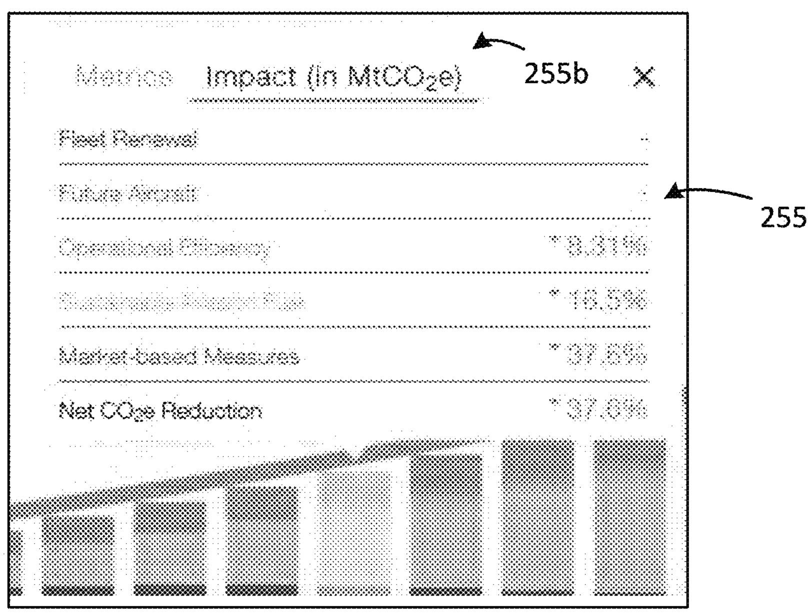


FIG. 14E

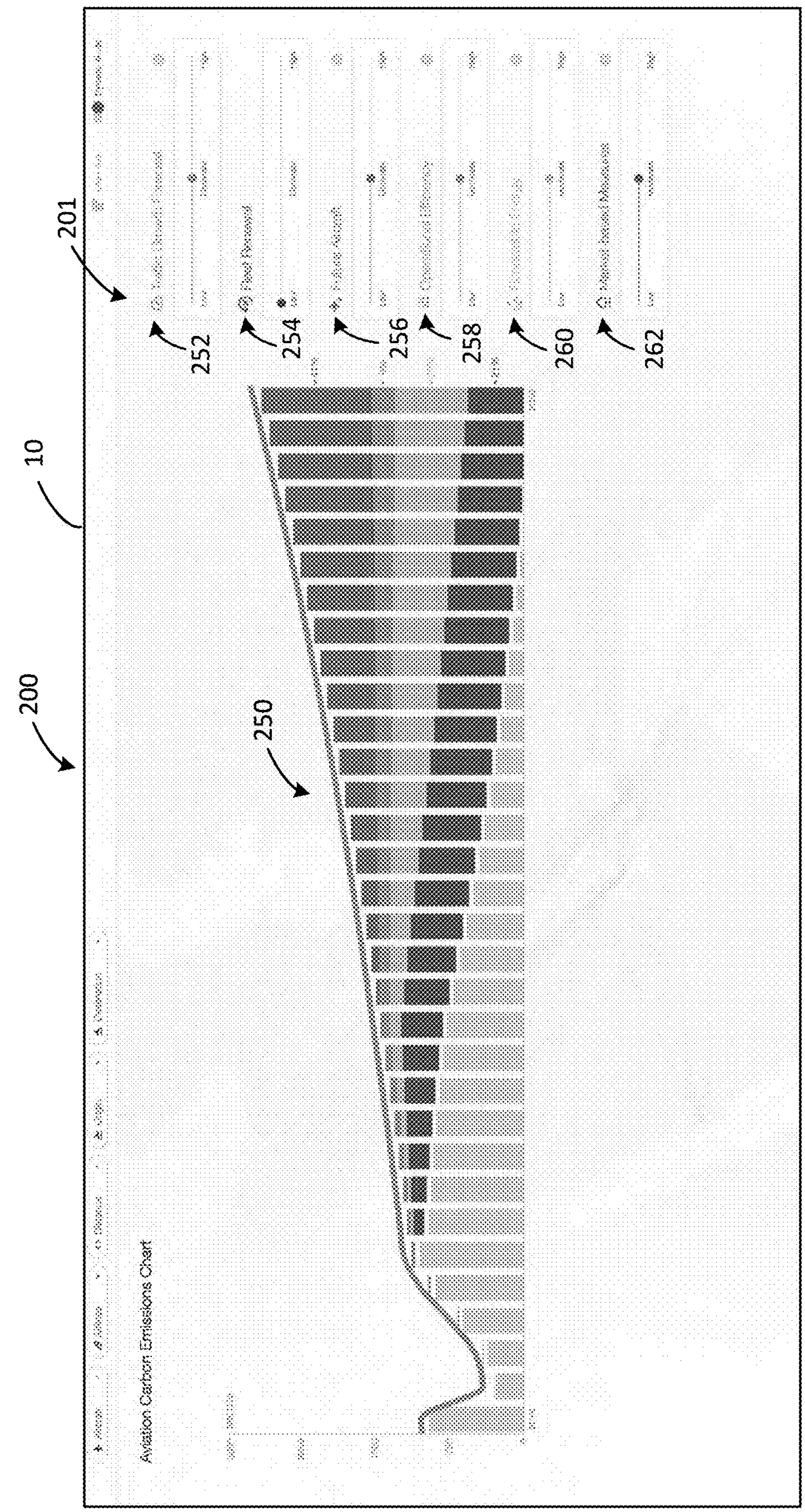

200
10
201
250
252
254
256
258
260
262
Aviation Carbon Emissions Chart

FIG. 15

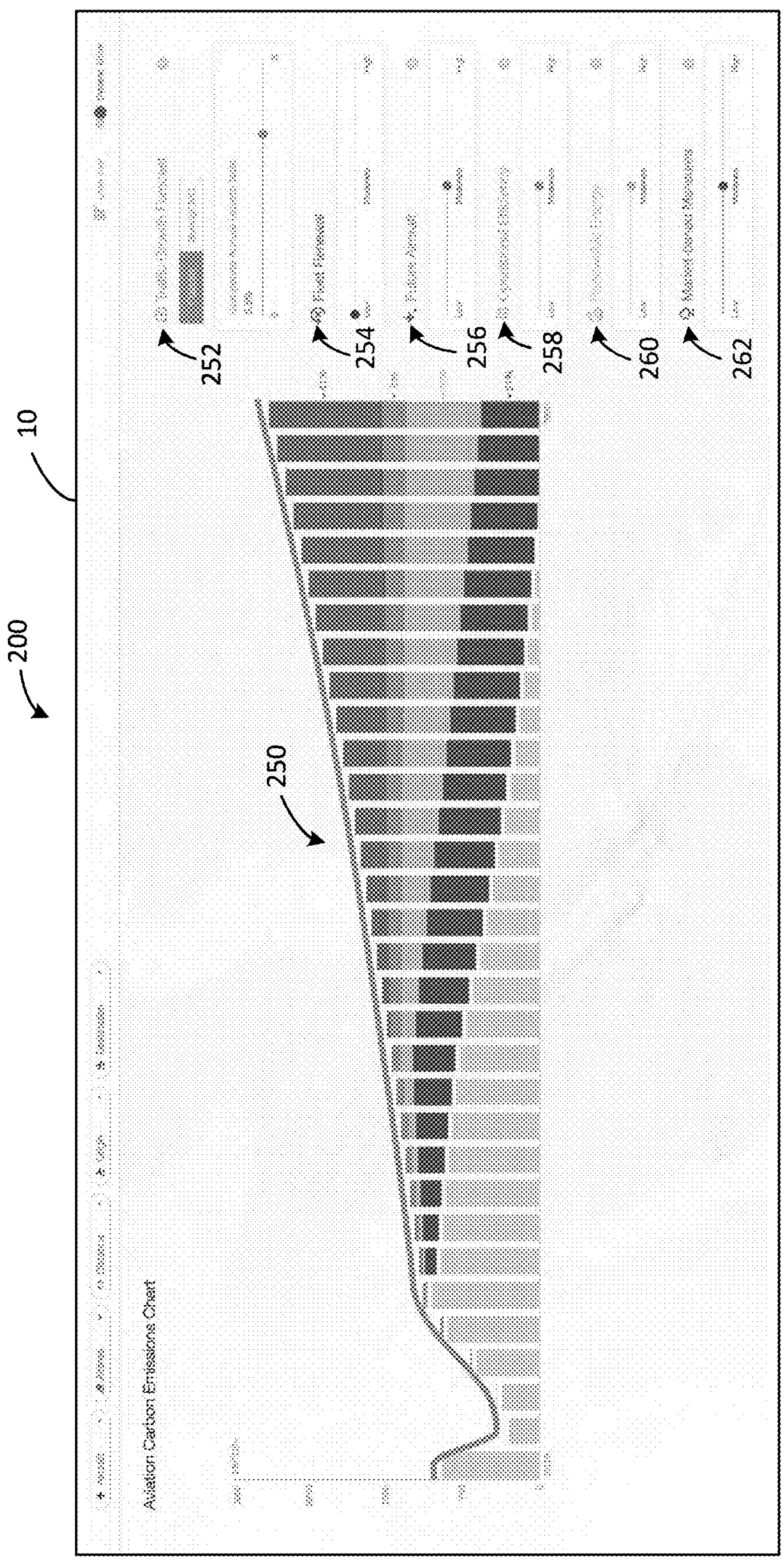

200
10
250
252
254
256
258
260
262
Aviation Carbon Emissions Chart

FIG. 16A

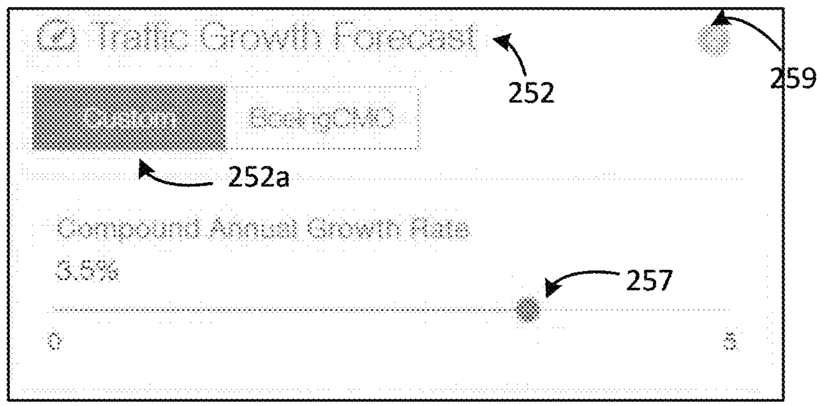


FIG. 16B

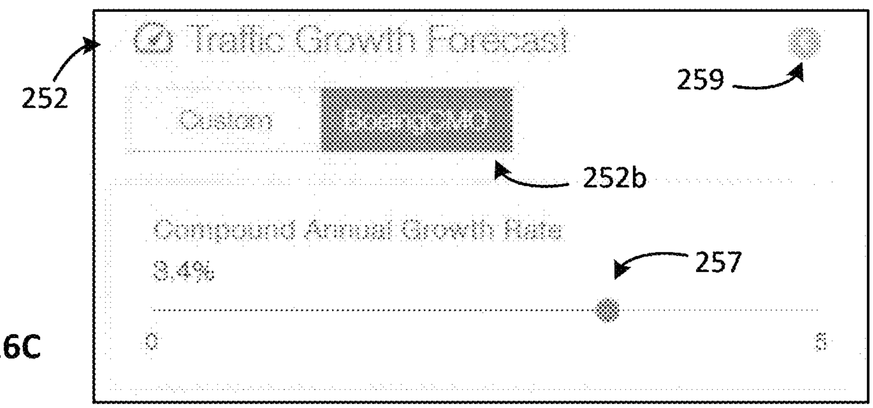


FIG. 16C

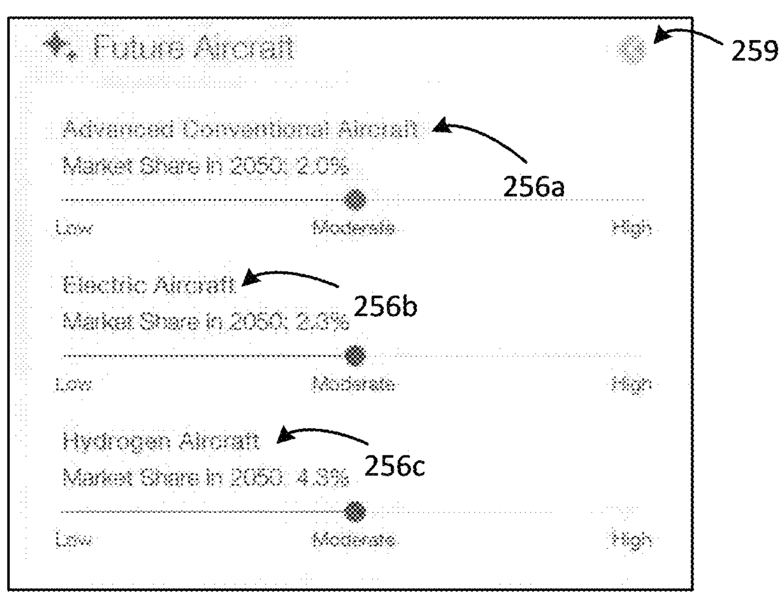
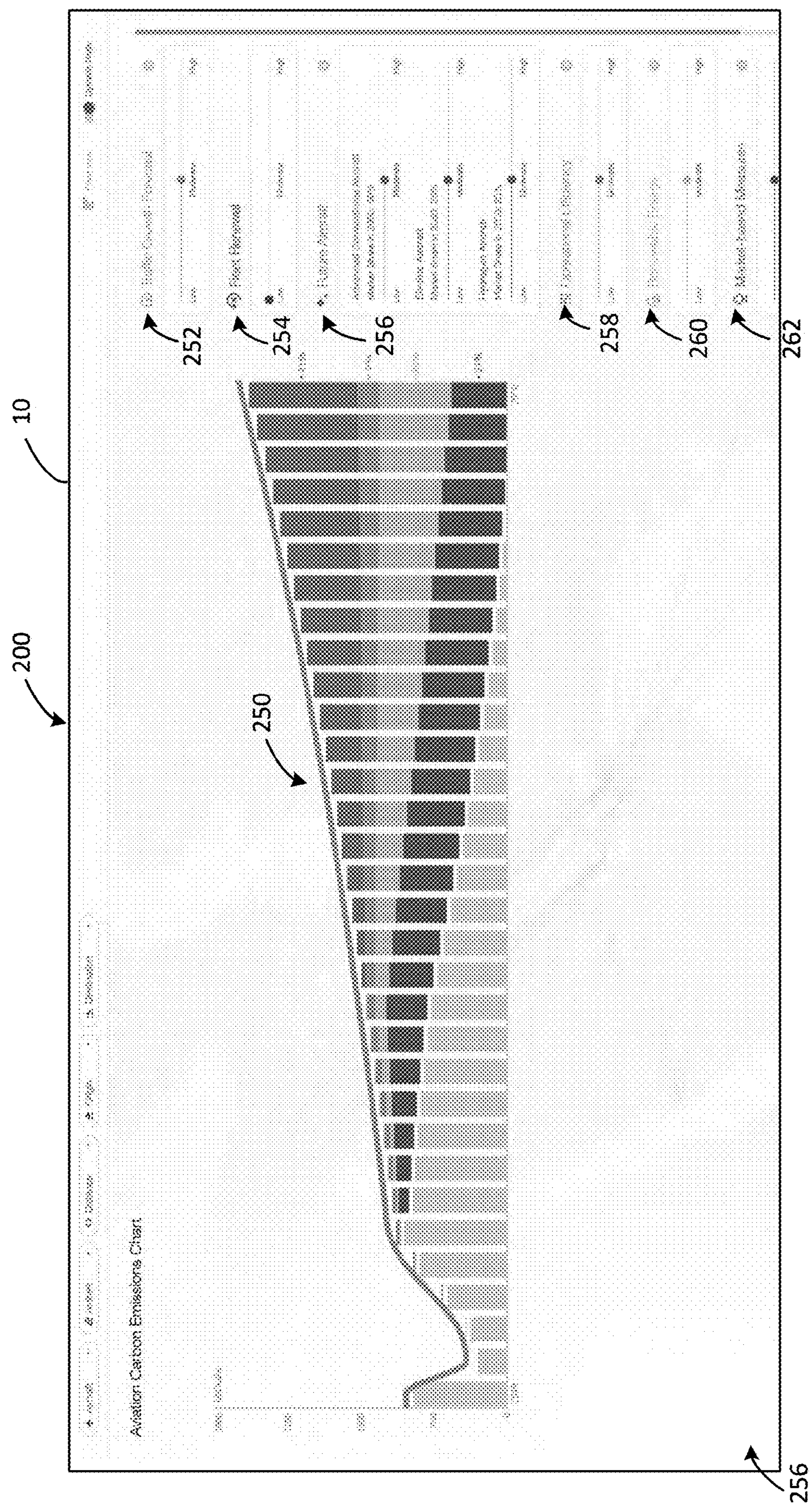


FIG. 17B



10
200
250
252
254
256
258
260
262
256
Aviation Carbon Emissions Chart

FIG. 17A

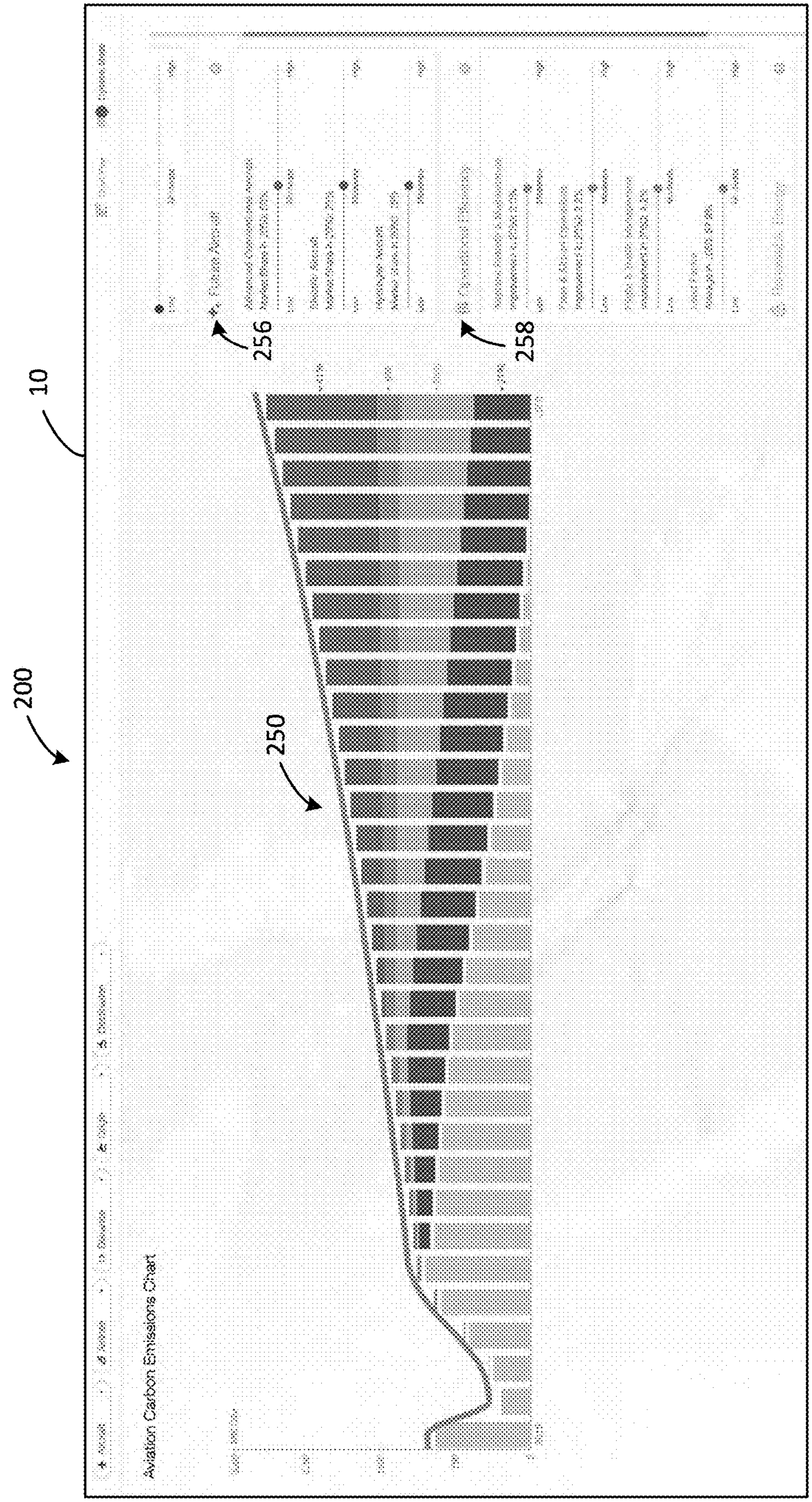


FIG. 18A

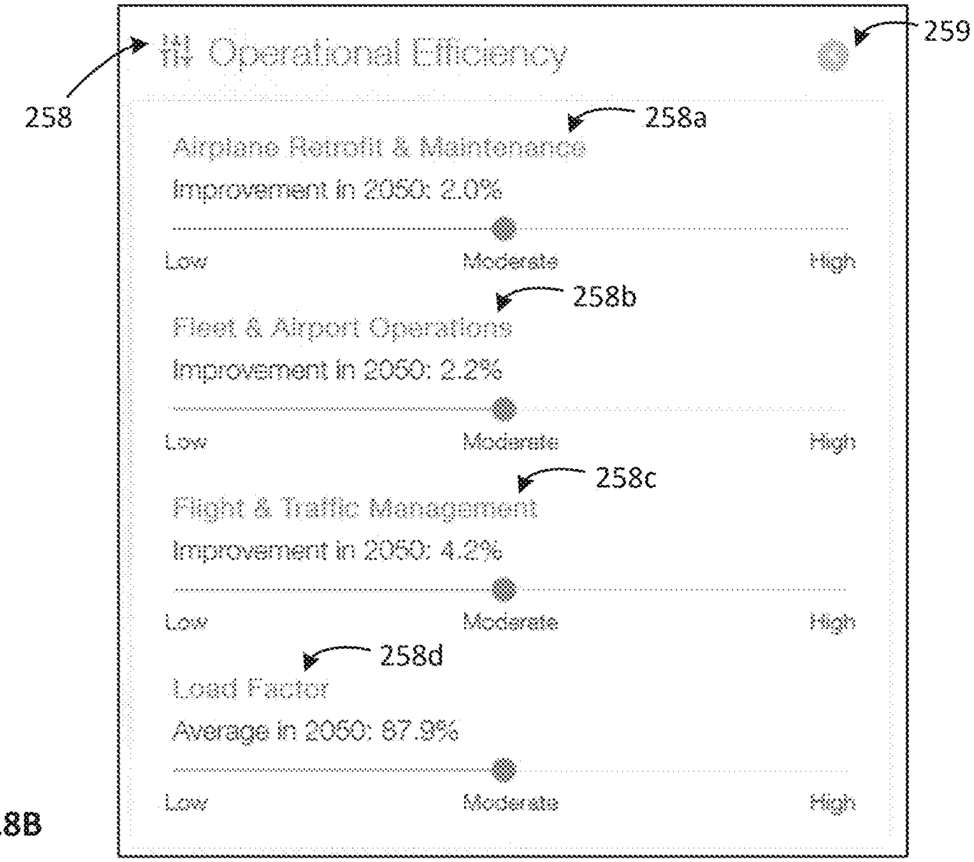


FIG. 18B

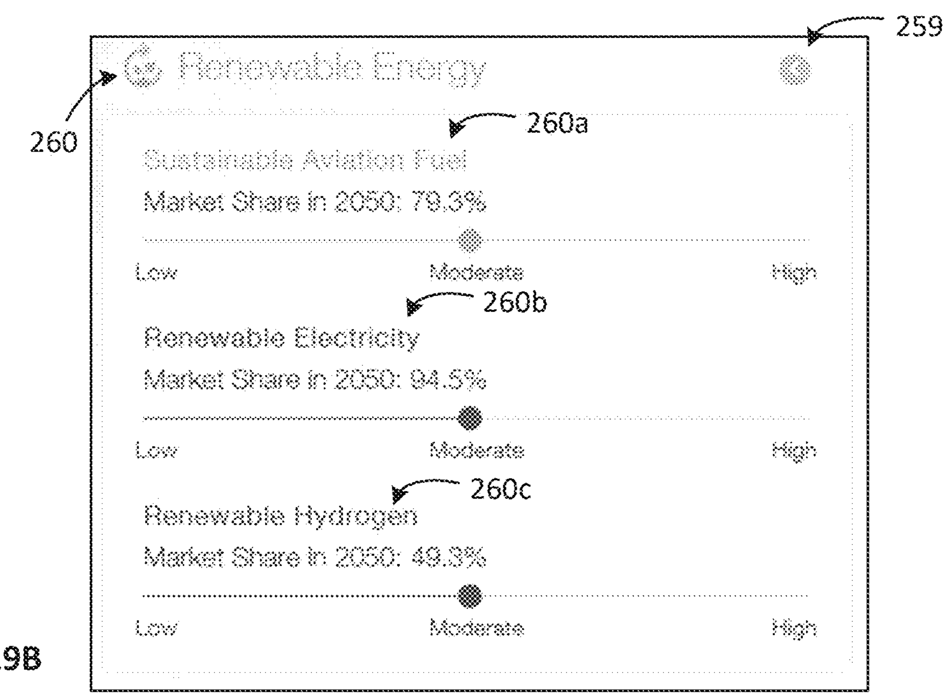


FIG. 19B

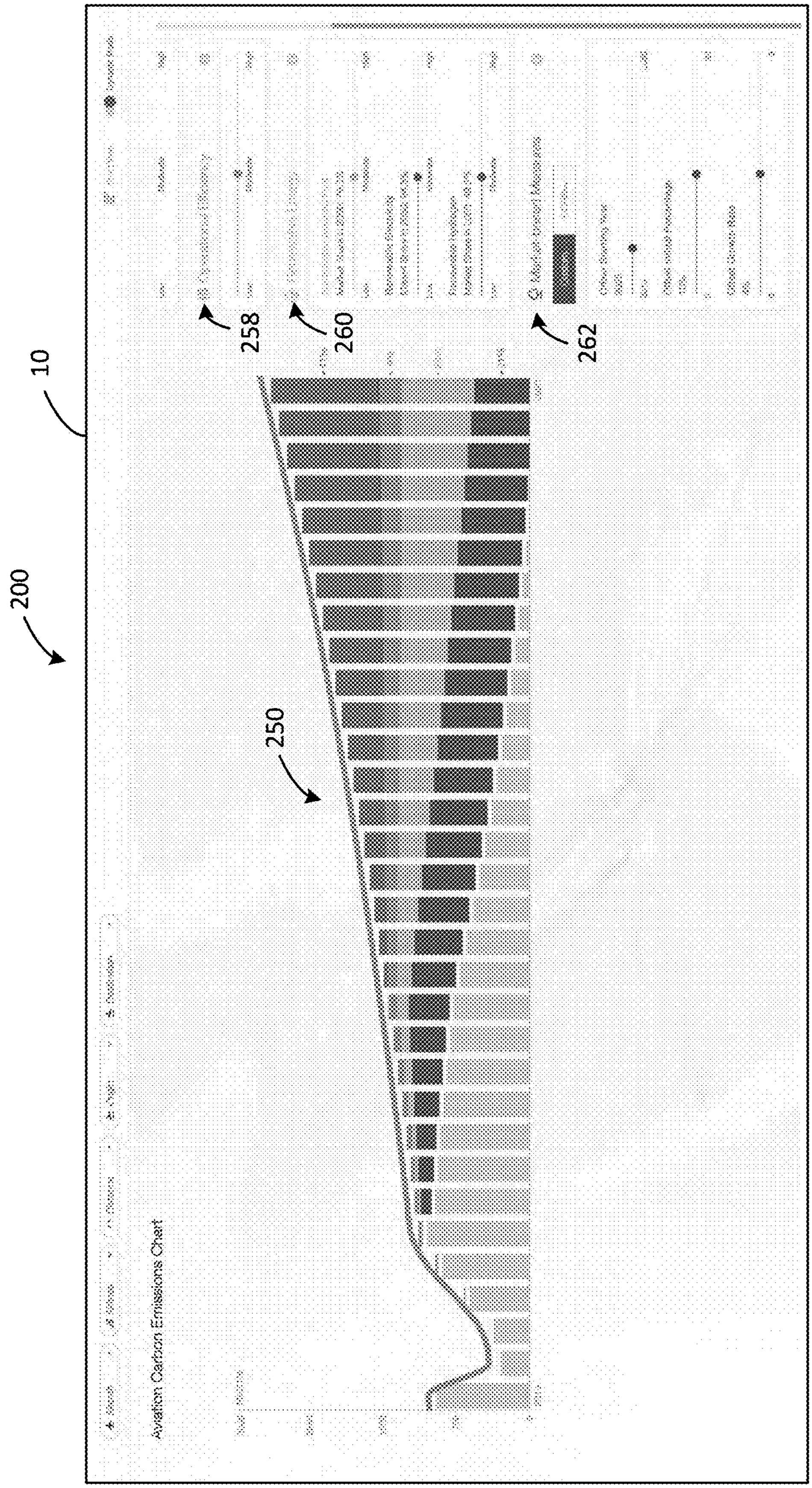


FIG. 19A

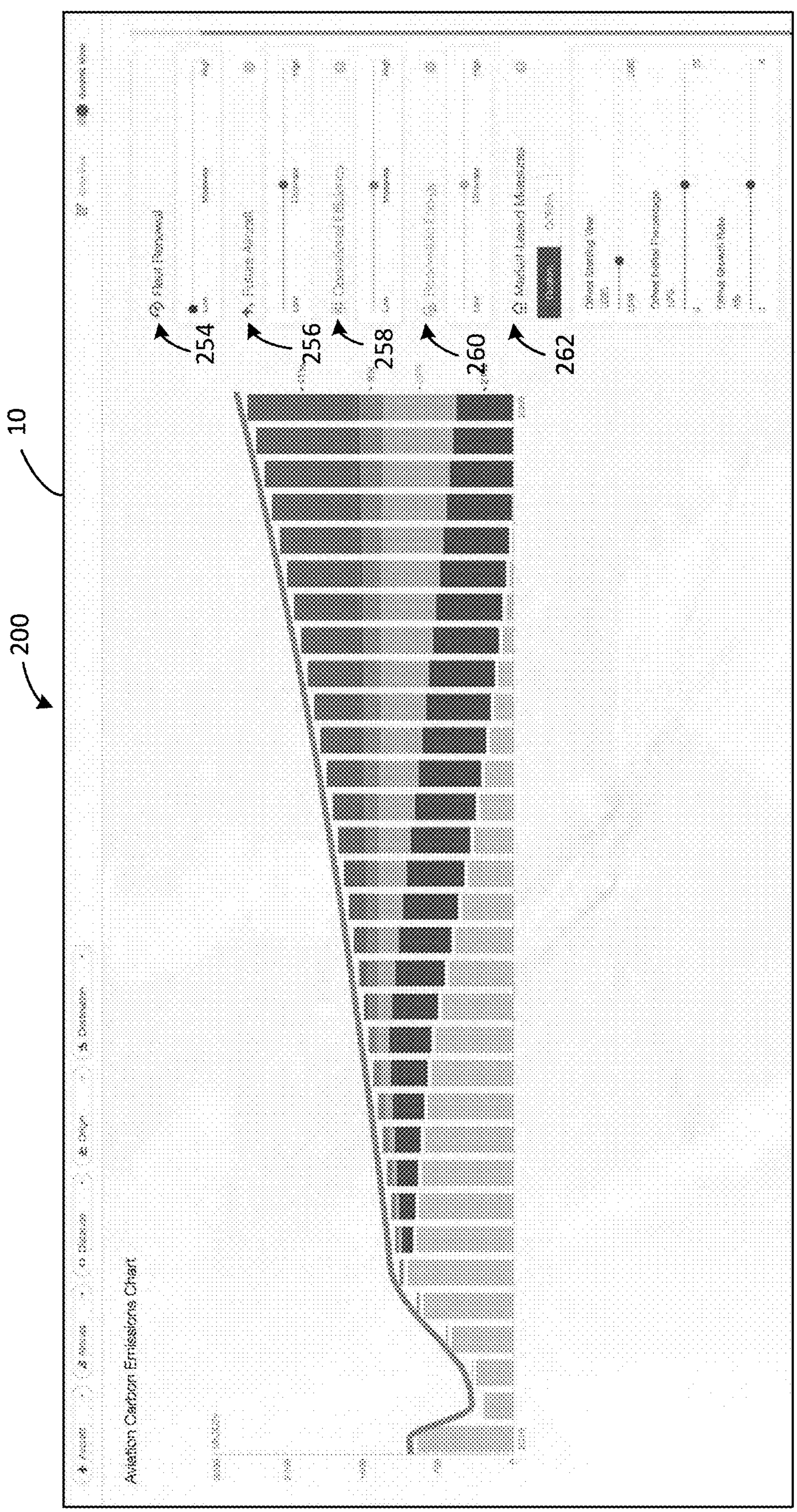


FIG. 20A

FIG. 20B

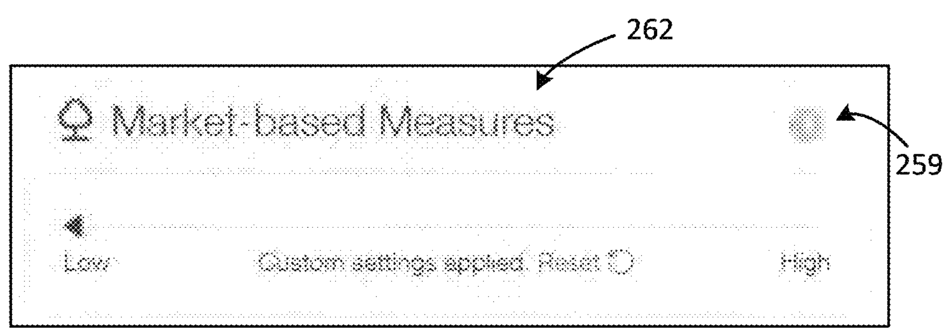


FIG. 20C

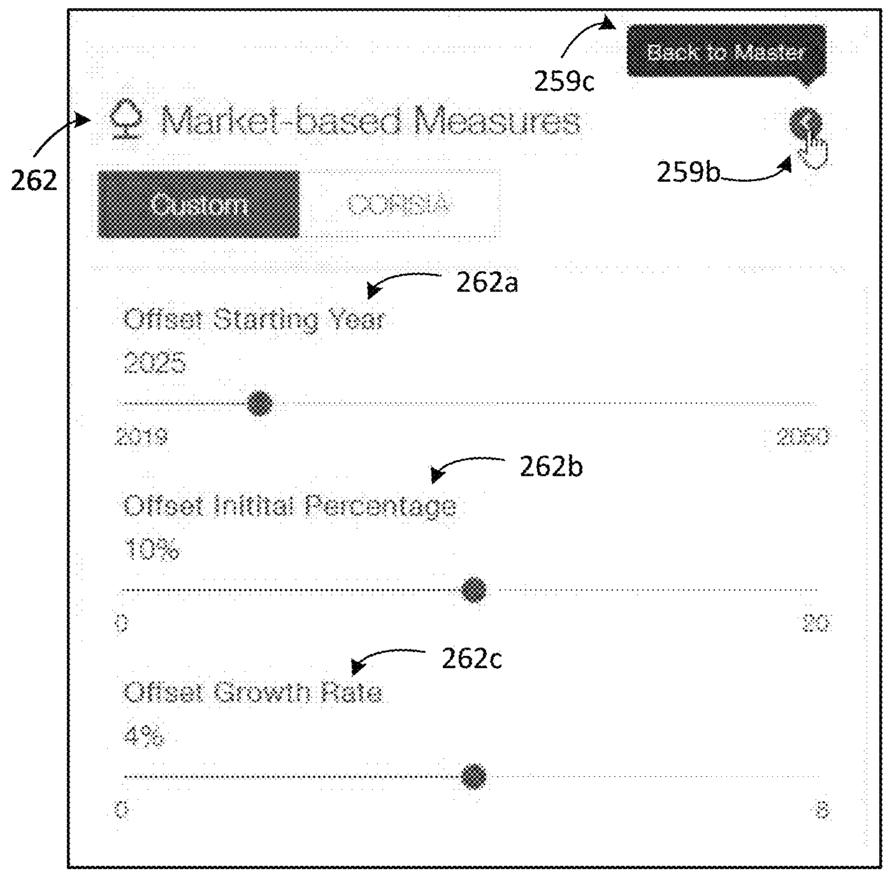


FIG. 20D

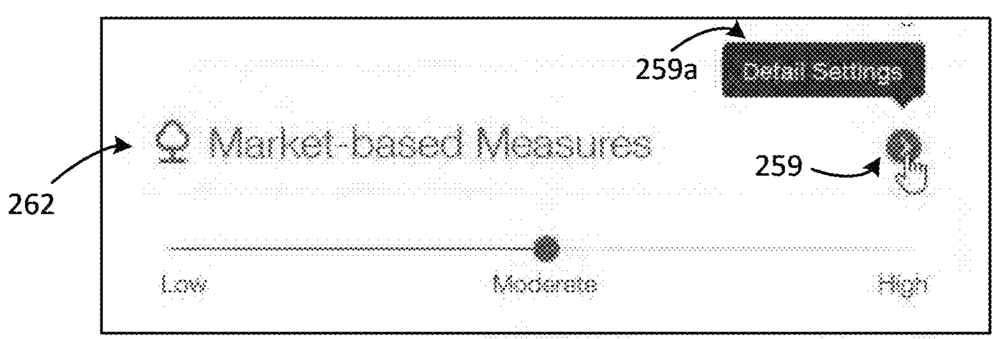


FIG. 20E

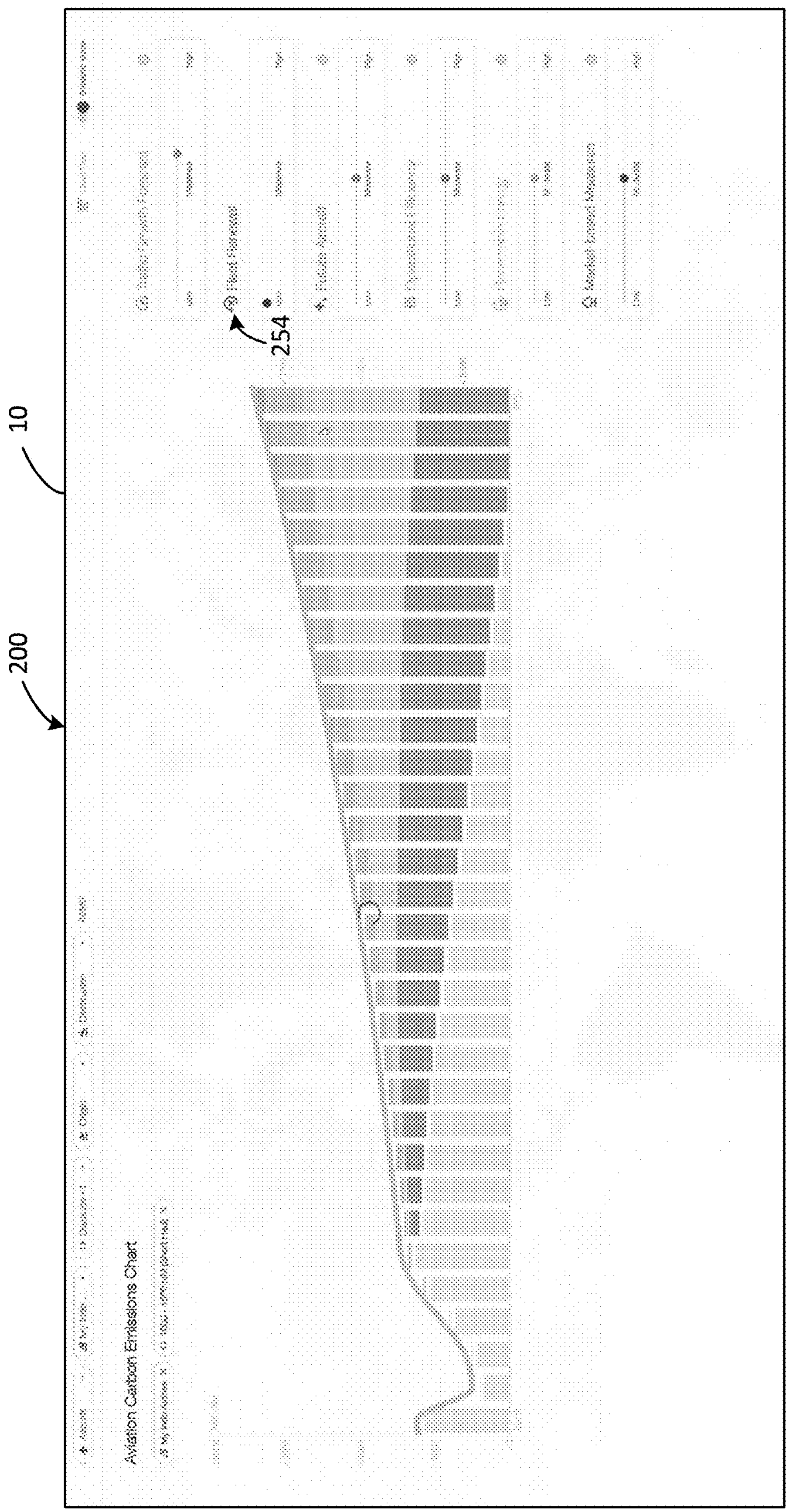


FIG. 21

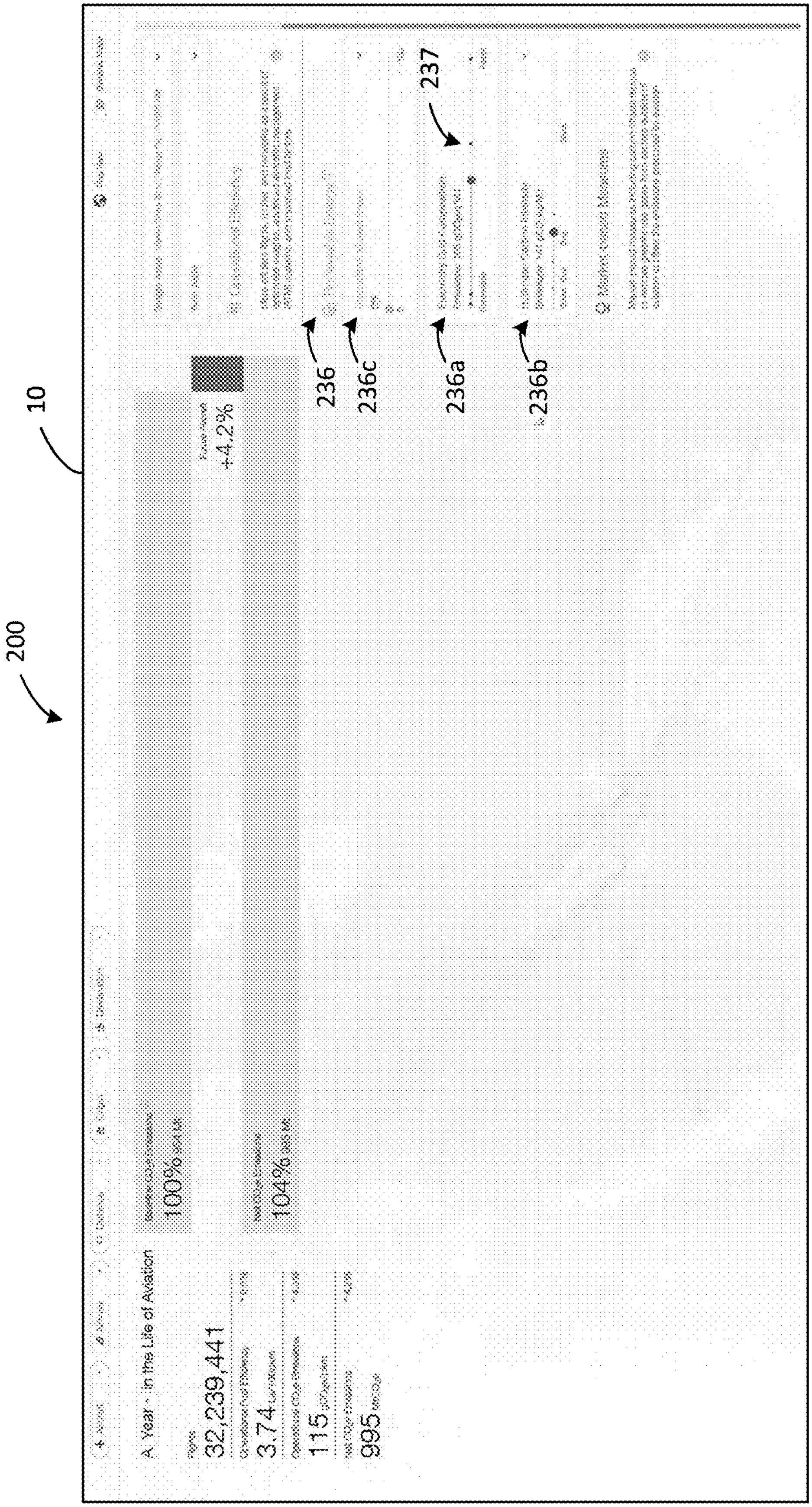

200
10
236
236c
236a
236b
237
A Year - in the Life of Aviation
32,239,441
3.74
115
995
100%
104%
+4.2%

FIG. 22A

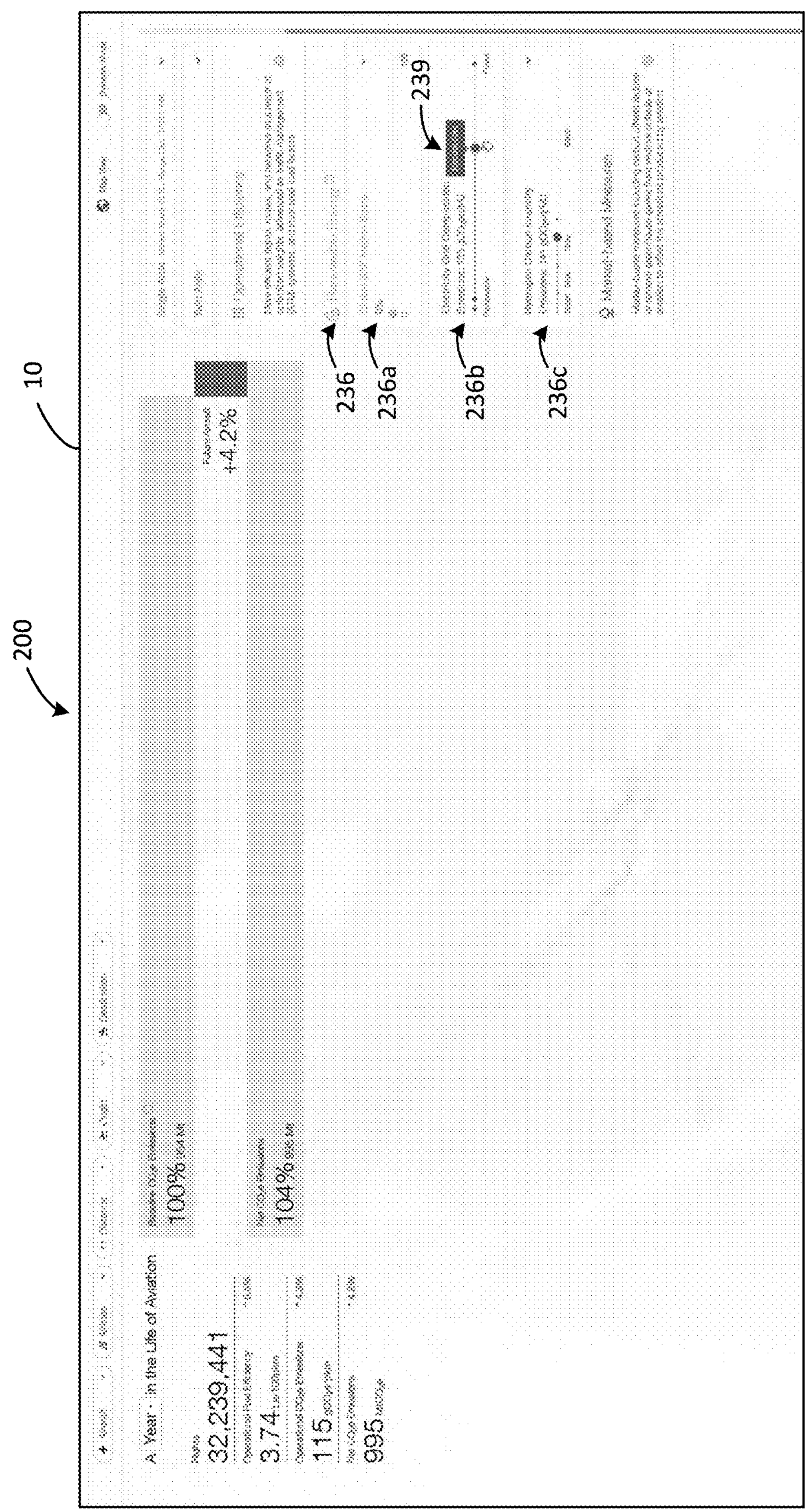

200
10
A Year in the Life of Aviation
32,239,441
3.74
115
995
100%
104%
+4.2%
236
236a
236b
236c
239

FIG. 22B

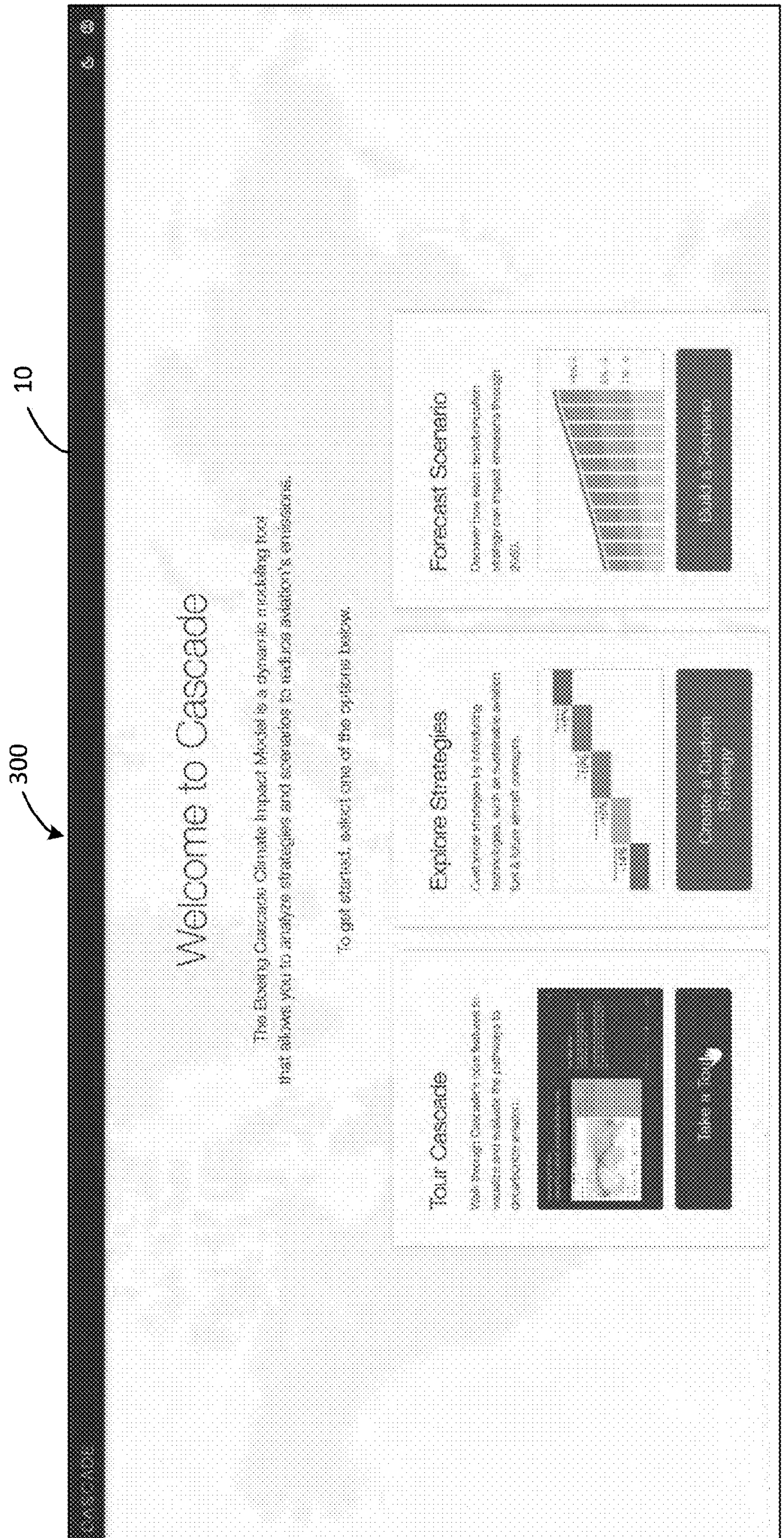

300
10
Welcome to Cascade
The Boeing Cascade Climate Impact Model is a dynamic modeling tool
that allows you to analyze strategies and scenarios to reduce aviation's emissions.
To get started, select one of the options below.
Tour Cascade
Explore Strategies
Forecast Scenario

FIG. 23

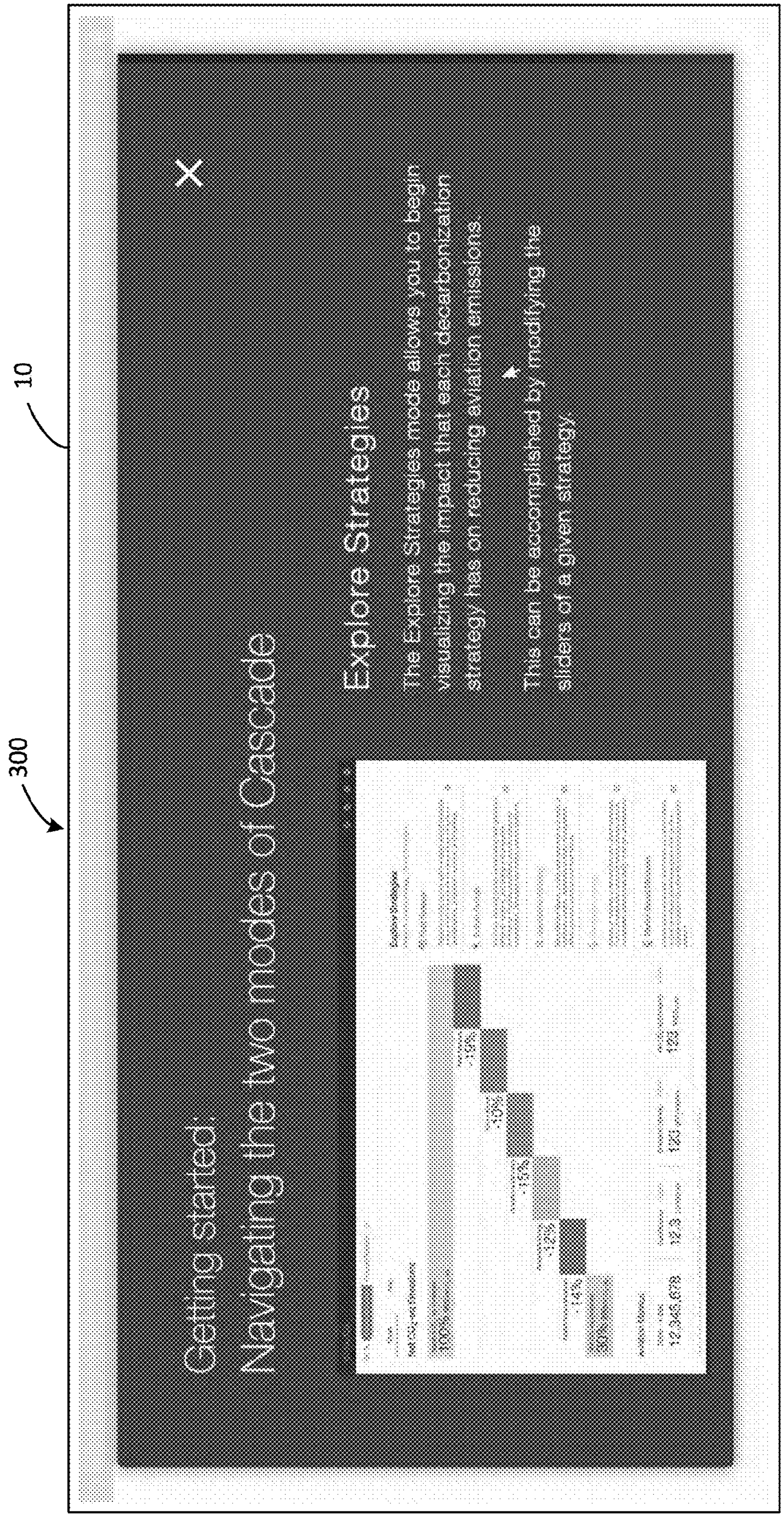

10
300
Getting started:
Navigating the two modes of Cascade
Explore Strategies
The Explore Strategies mode allows you to begin visualizing the impact that each decarbonization strategy has on reducing aviation emissions.
This can be accomplished by modifying the sliders of a given strategy

FIG. 24A

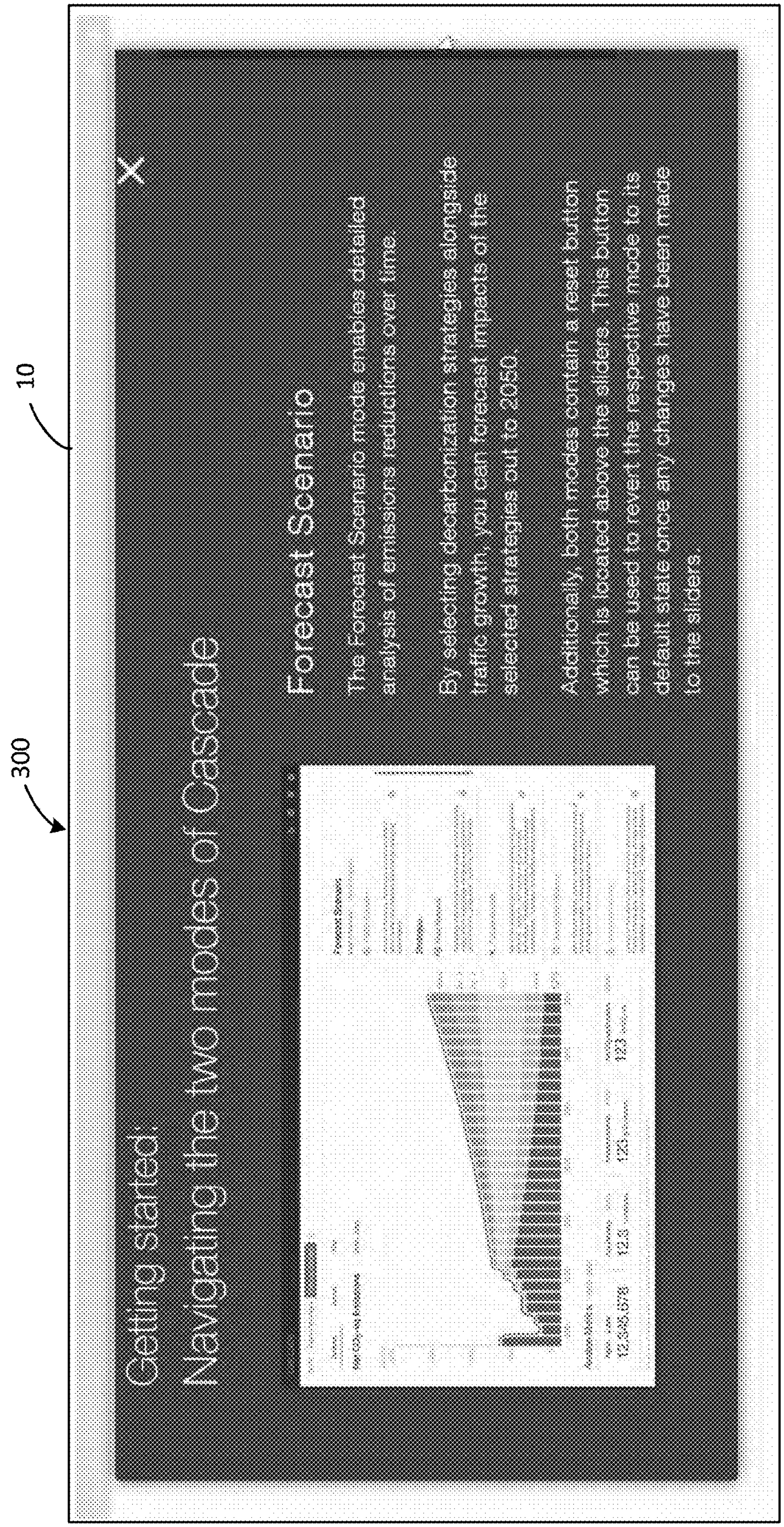

10
300
Getting started:
Navigating the two modes of Cascade
Forecast Scenario
The Forecast Scenario mode enables detailed analysis of emissions reductions over time.
By selecting decarbonization strategies alongside traffic growth, you can forecast impacts of the selected strategies out to 2050.
Additionally, both modes contain a reset button which is located above the sliders. This button can be used to revert the respective mode to its default state once any changes have been made to the sliders.

FIG. 24B

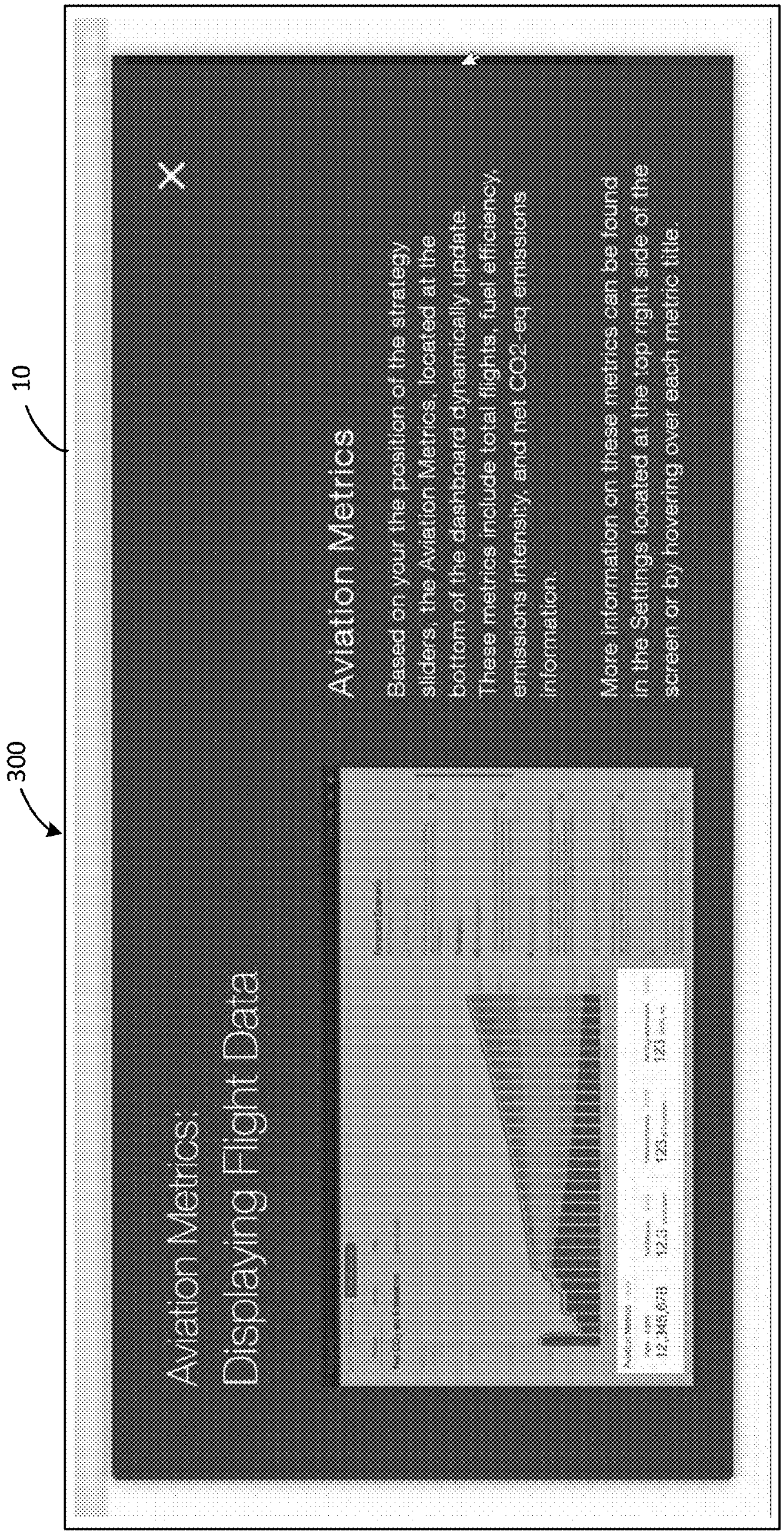

10
300
Aviation Metrics:
Displaying Flight Data
Aviation Metrics
Based on your the position of the strategy sliders, the Aviation Metrics, located at the bottom of the dashboard dynamically update. These metrics include total flights, fuel efficiency, emissions intensity, and net CO2-eq emissions information.
More information on these metrics can be found in the Settings located at the top right side of the screen or by hovering over each metric tile.

FIG. 24C

300

10

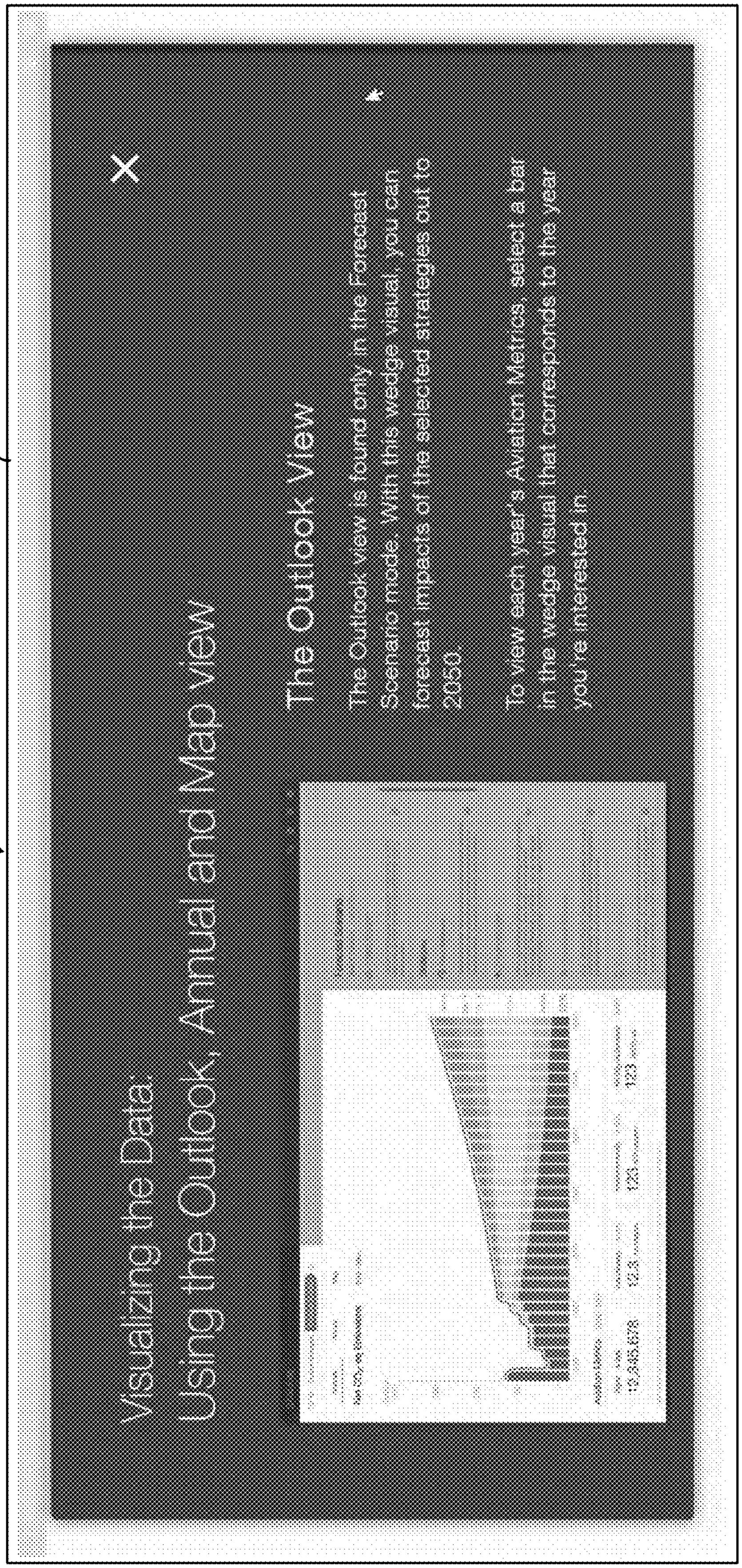


FIG. 24D

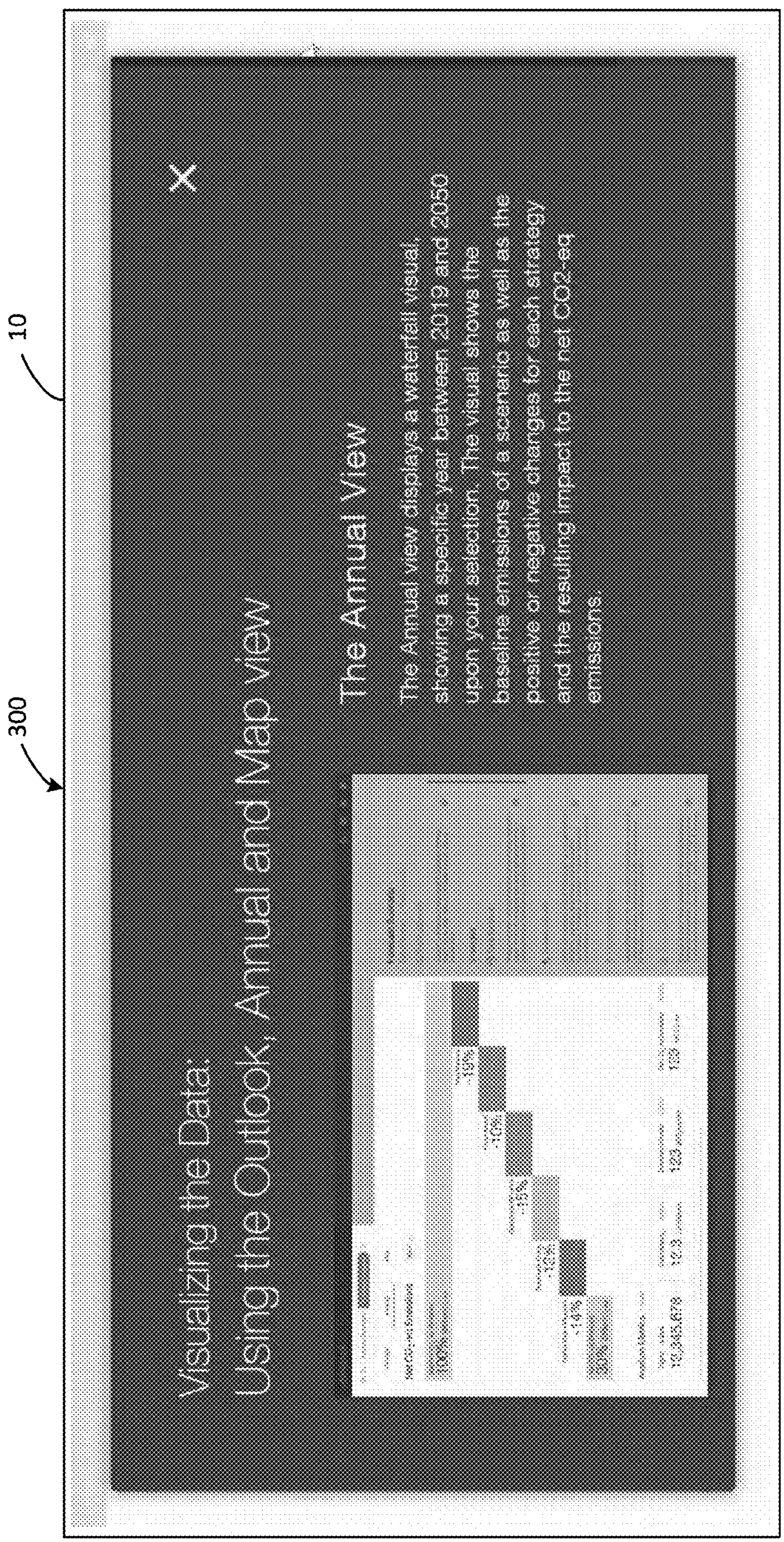

10
300
Visualizing the Data:
Using the Outlook, Annual and Map view
The Annual View
The Annual view displays a waterfall visual, showing a specific year between 2019 and 2050 upon your selection. The visual shows the baseline emissions of a scenario as well as the positive or negative changes for each strategy and the resulting impact to the net CO2-eq emissions.

FIG. 24E

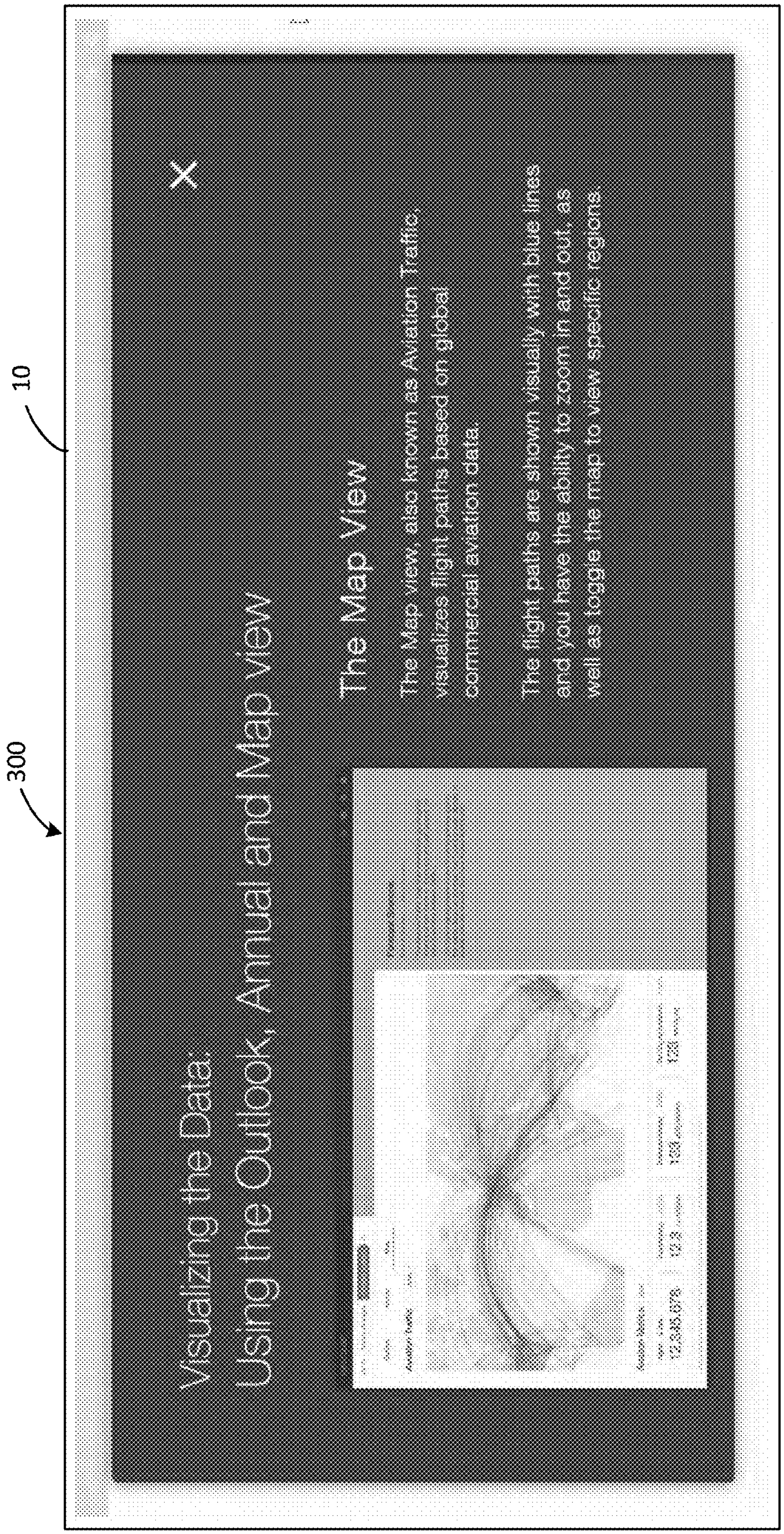

10
300
Visualizing the Data:
Using the Outlook, Annual and Map view
The Map View
The Map view, also known as Aviation Traffic, visualizes flight paths based on global commercial aviation data.
The flight paths are shown visually with blue lines and you have the ability to zoom in and out, as well as toggle the map to view specific regions

FIG. 24F

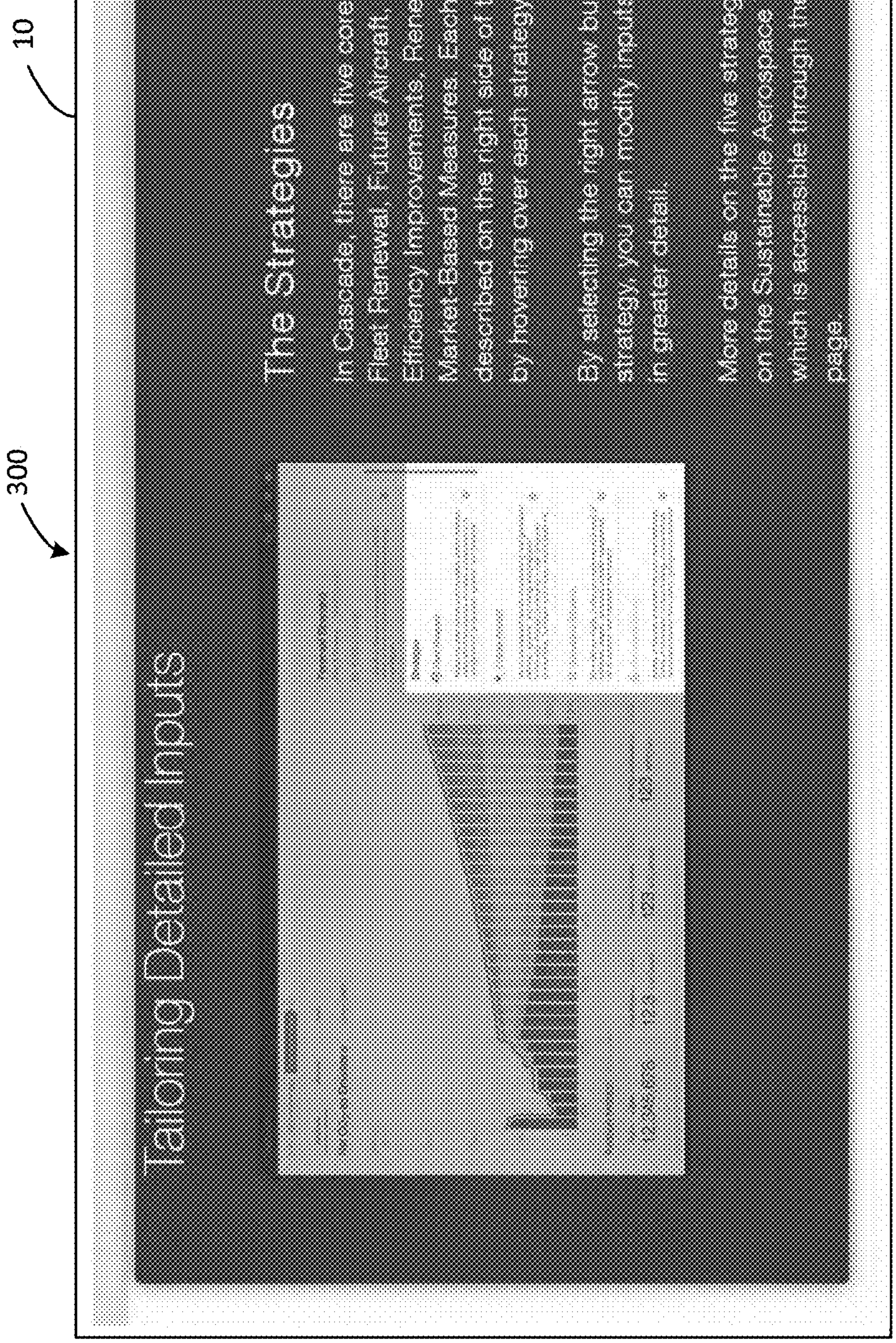

10
300
Tailoring Detailed Inputs
The Strategies
In Cascade, there are five core strategies: Fleet Renewal, Future Aircraft, Operational Efficiency Improvements, Renewable Energy, and Market-Based Measures. Each strategy is described on the right side of the dashboard or by hovering over each strategy title.
By selecting the right arrow button for each strategy, you can modify inputs for each strategy in greater detail.
More details on the five strategies can be found on the Sustainable Aerospace Together page, which is accessible through the Help & Support page.

FIG. 24G

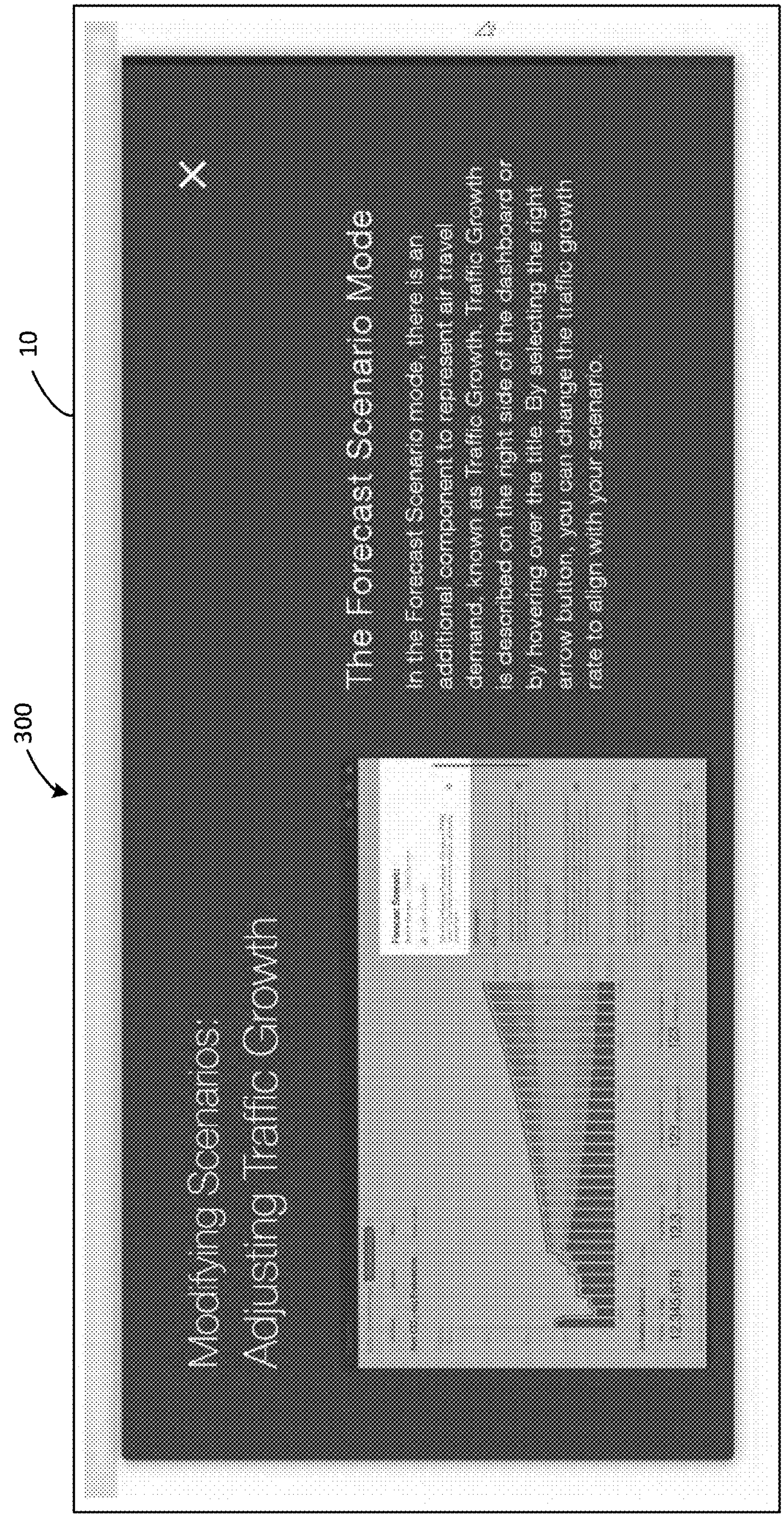

300
10
Modifying Scenarios:
Adjusting Traffic Growth
The Forecast Scenario Mode
In the Forecast Scenario mode, there is an additional component to represent air travel demand, known as Traffic Growth. Traffic Growth is described on the right side of the dashboard or by hovering over the tile. By selecting the right arrow button, you can change the traffic growth rate to align with your scenario.

FIG. 24H

300

10

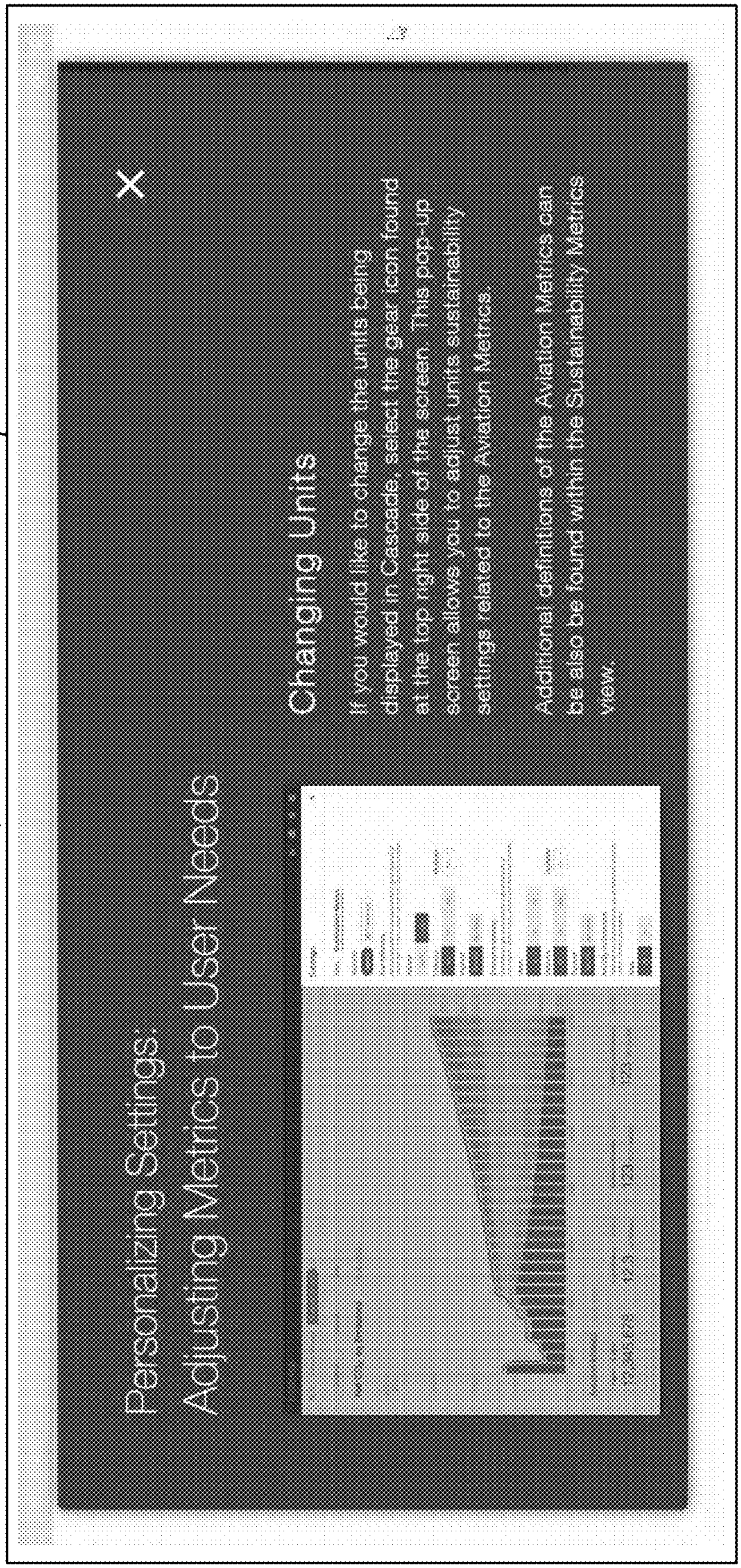


FIG. 24I

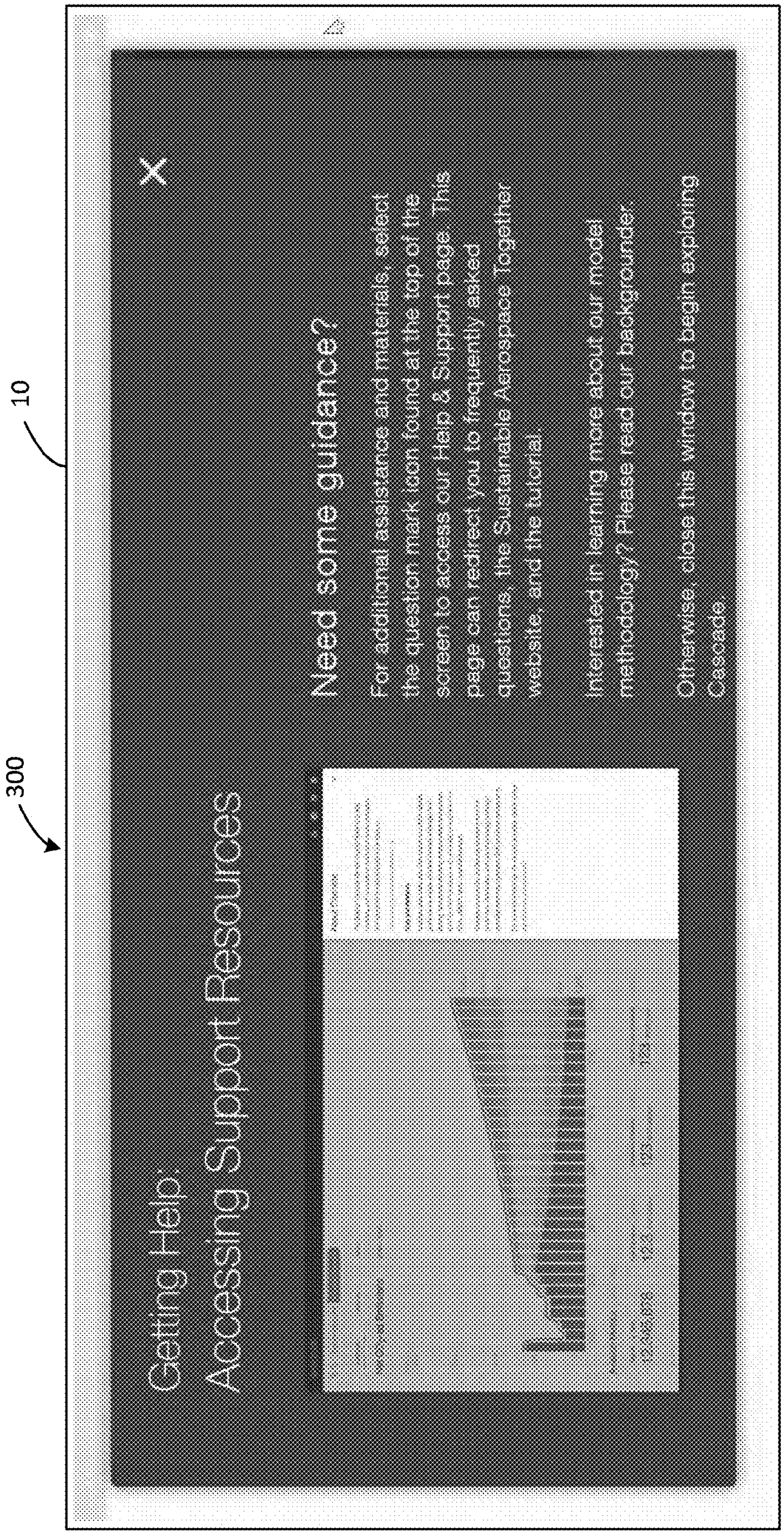

10
300
Getting Help:
Accessing Support Resources
Need some guidance?
For additional assistance and materials, select the question mark icon found at the top of the screen to access our Help & Support page. This page can redirect you to frequently asked questions, the Sustainable Aerospace Together website, and the tutorial.
Interested in learning more about our model methodology? Please read our backgrounder.
Otherwise, close this window to begin exploring Cascade.

FIG. 24J

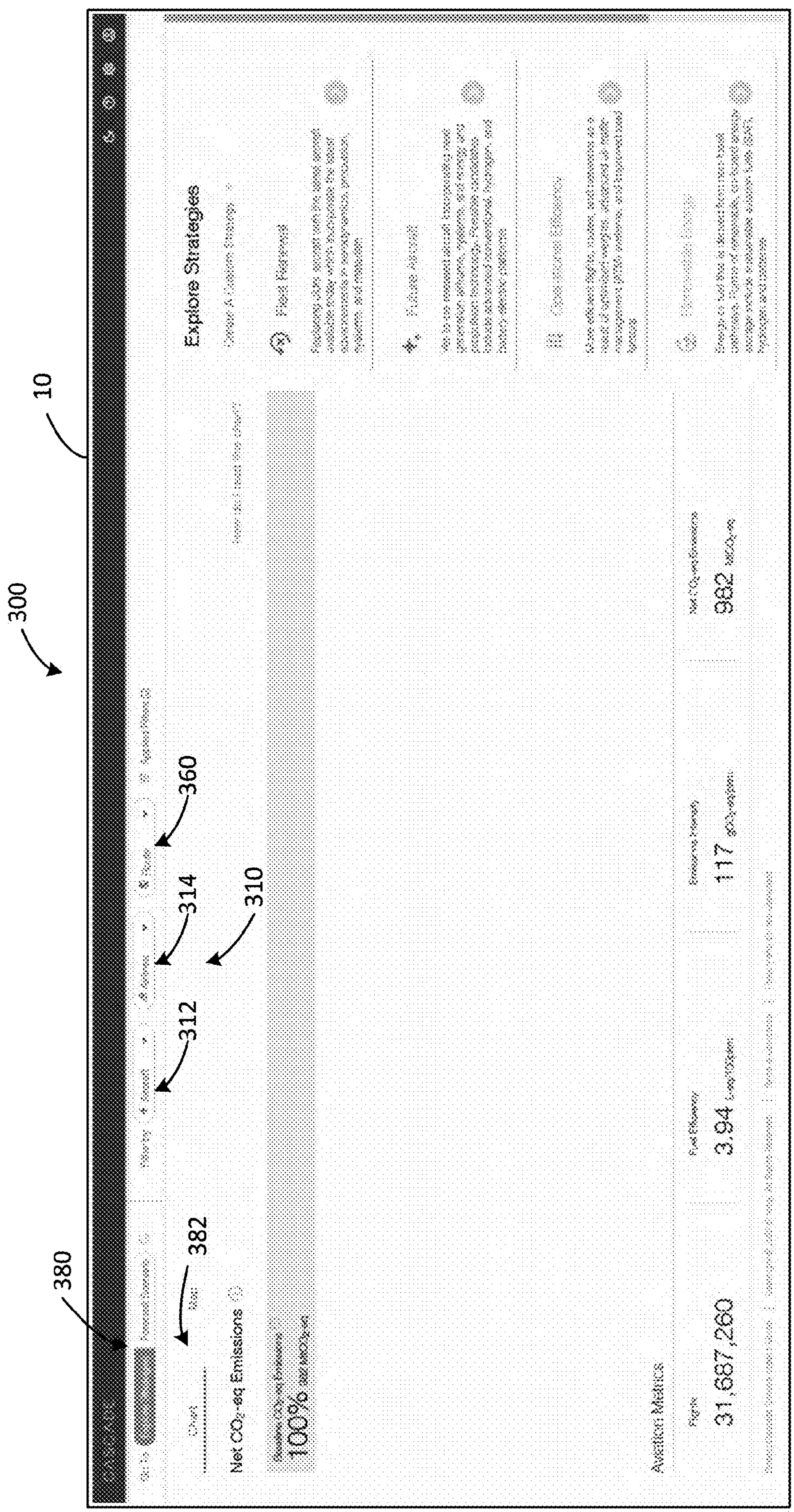

300
10
380
382
312
314
310
360
Explore Strategies
Net CO2-eq Emissions
100%
Aviation Metrics
31,687,260
3.94
117
982

FIG. 25A

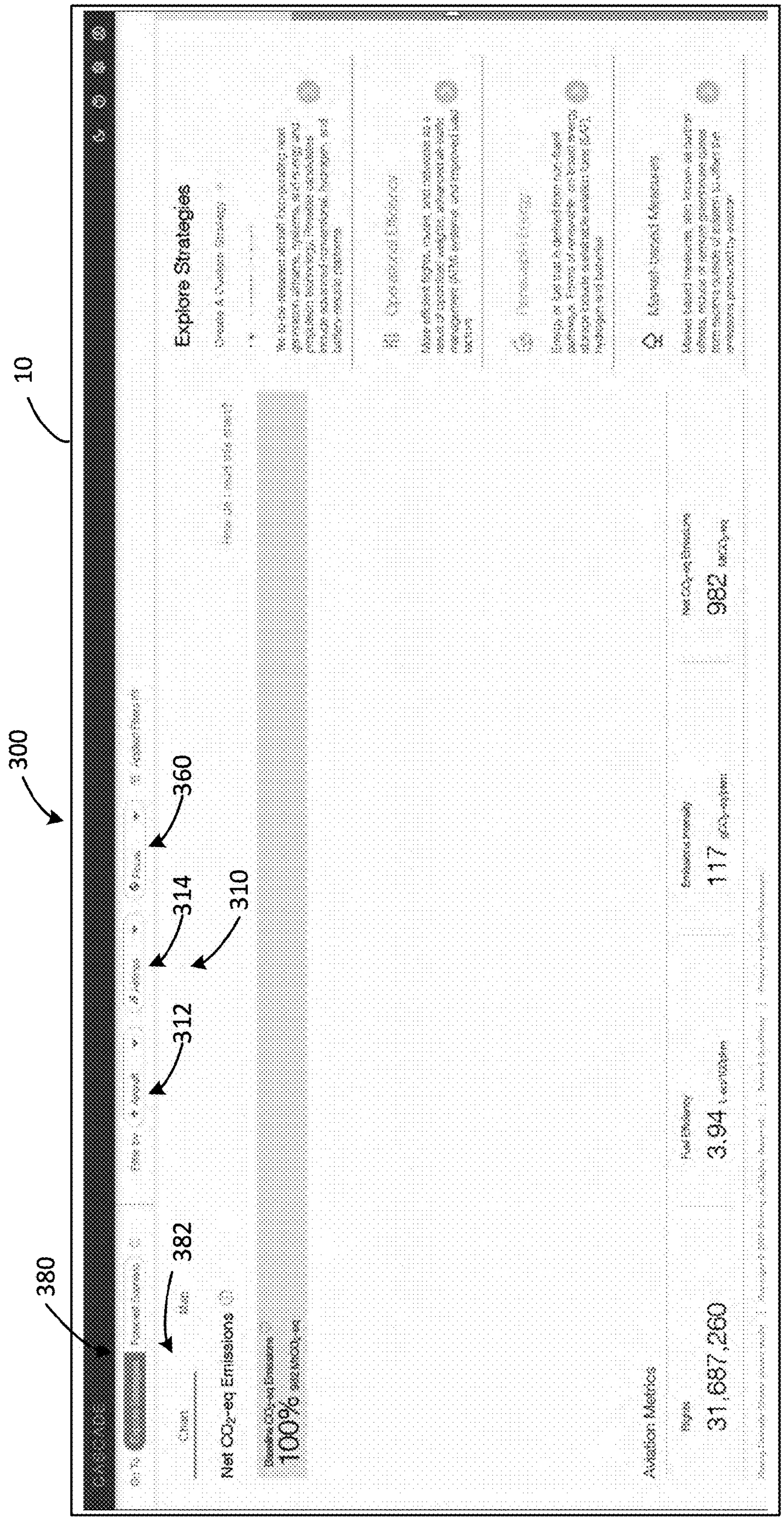

10
300
380
382
312
314
310
360
Net CO2-eq Emissions
100%
Explore Strategies
Aviation Metrics
31,687,260
3.94
117
982

FIG. 25B

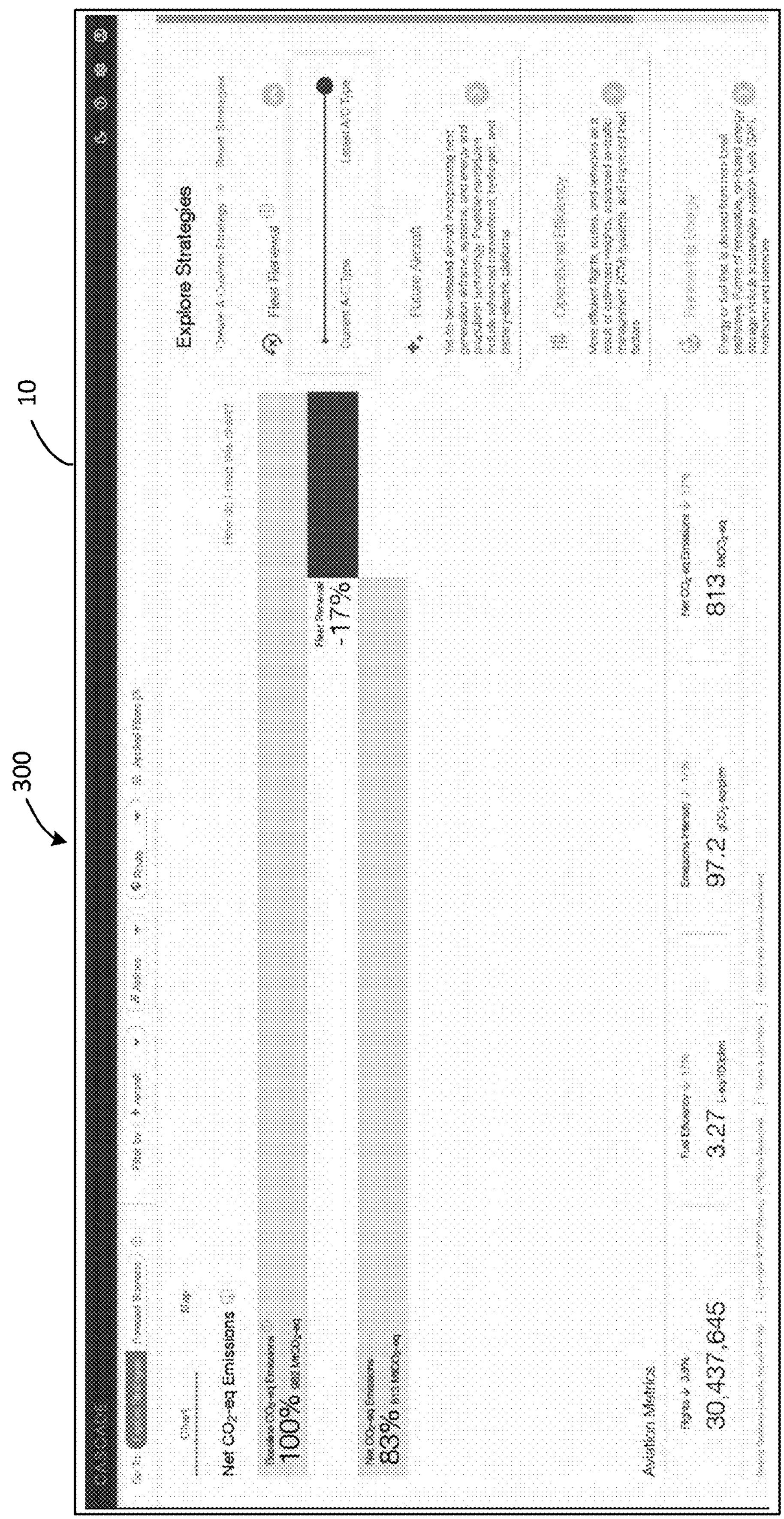

300
10
Net CO2-eq Emissions
100%
83%
-17%
Explore Strategies
Aviation Metrics
30,437,645
3.27
97.2
813

FIG. 26

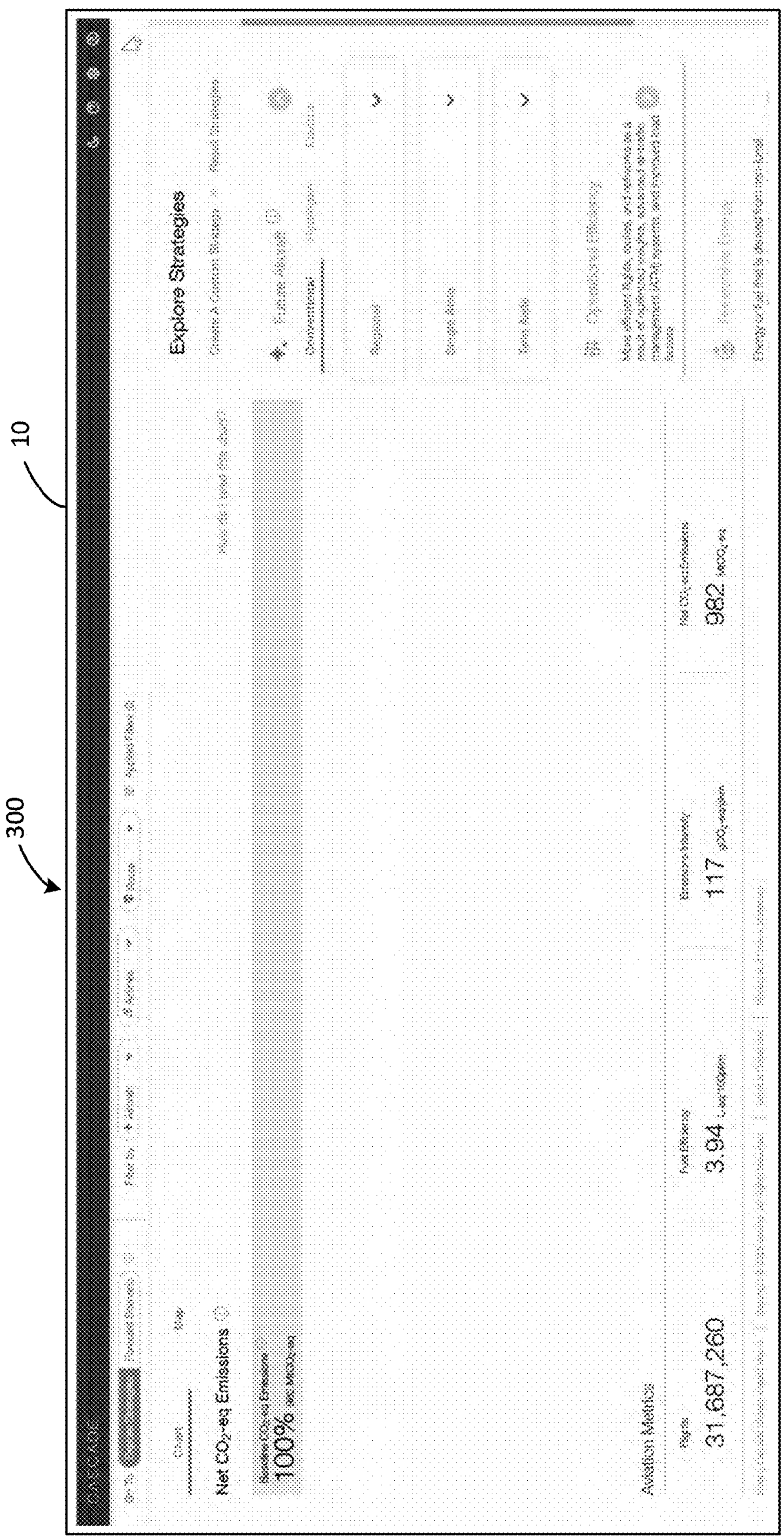

10
300
Explore Strategies
Net CO2-eq Emissions
100%
Aviation Metrics
31,687,260
3.94
117
982

FIG. 27A

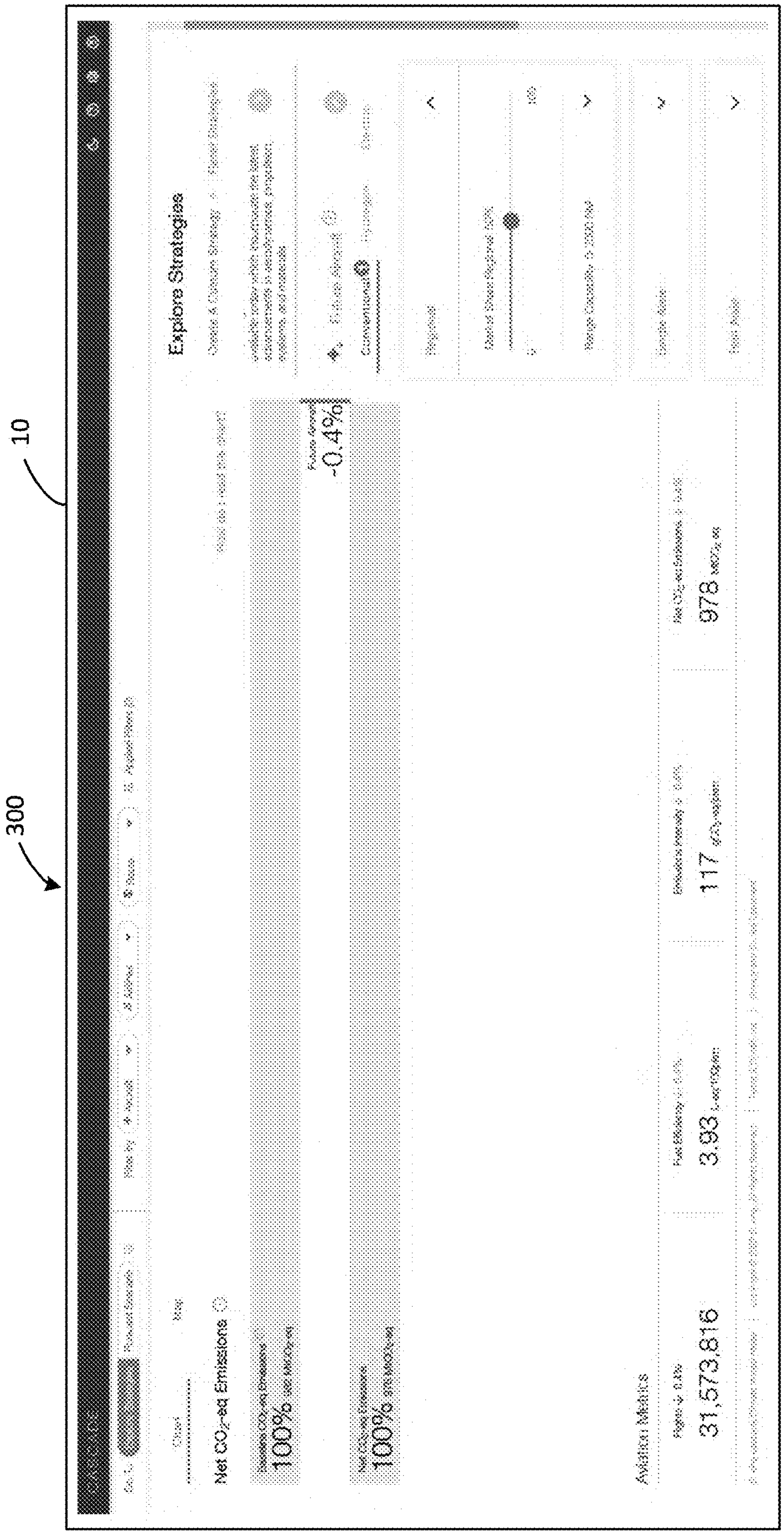

300
10
Net CO2-eq Emissions
100%
100%
-0.4%
Explore Strategies
Aviation Metrics
31,573,816
3.93
117
978

FIG. 27B

300

10

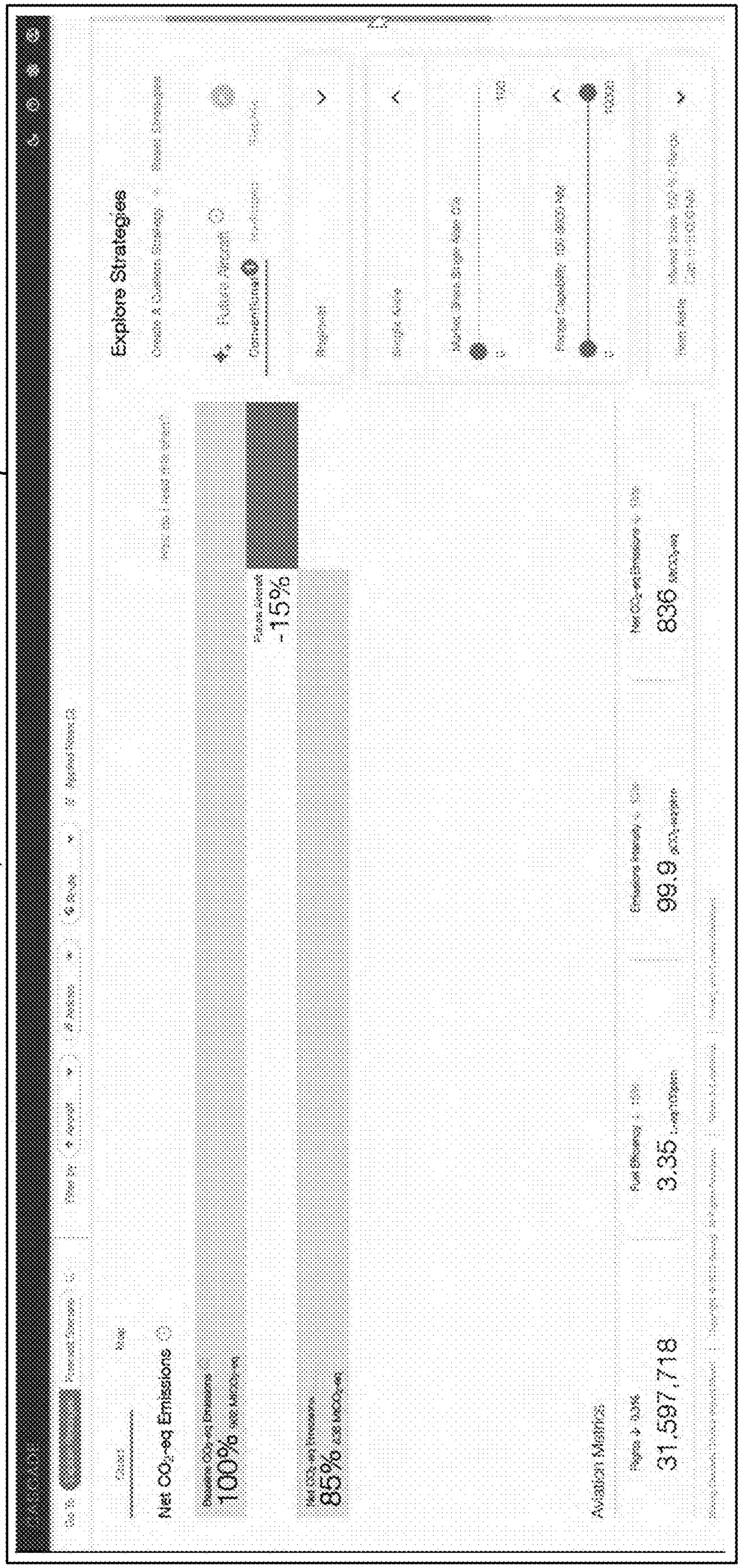


FIG. 27C


300
10
Net CO2-eq Emissions
100%
70%
-30%
Explore Strategies
Aviation Metrics
30,672,144
2.76
82.3
688

FIG. 27D

10

300

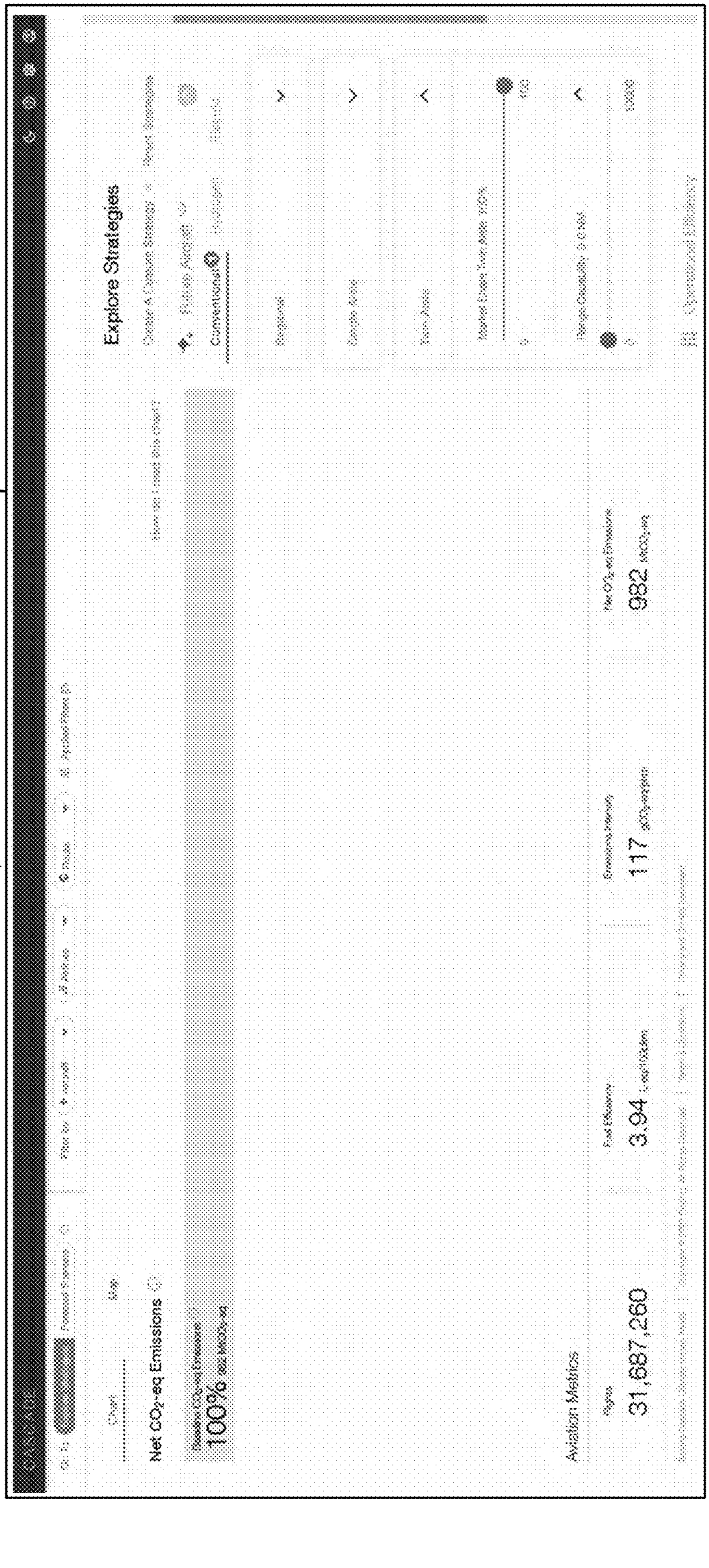


FIG. 27E

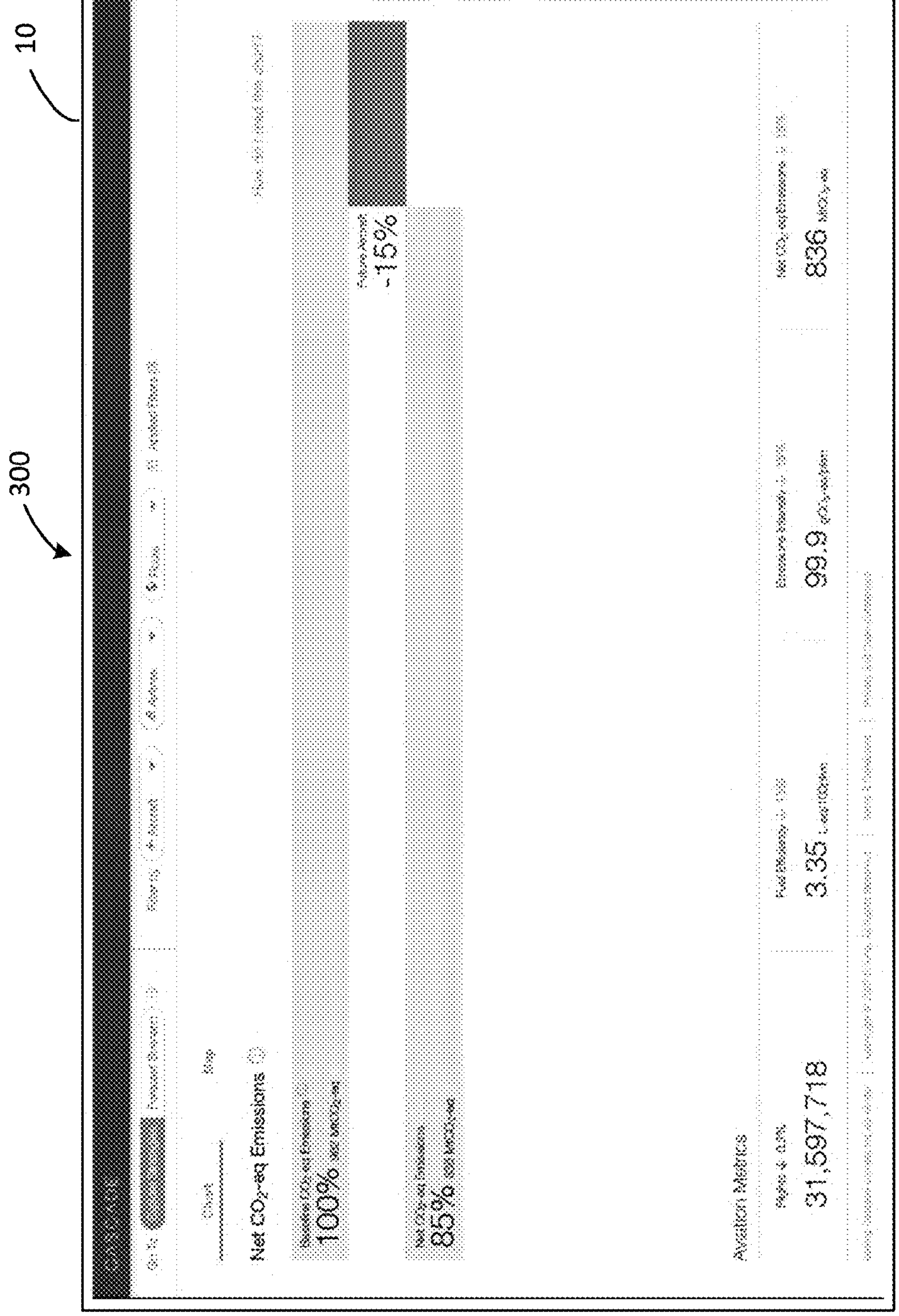

10
300
Net CO_2-eq Emissions
100%
85%
-15%
Explore Strategies
Aviation Metrics
31,597,718
3.35
99.9
836

FIG. 27F


300
10
Net CO2-eq Emissions
100%
84%
-16%
Explore Strategies
Aviation Metrics
31,370,830
3.32
98.9
827

FIG. 27G

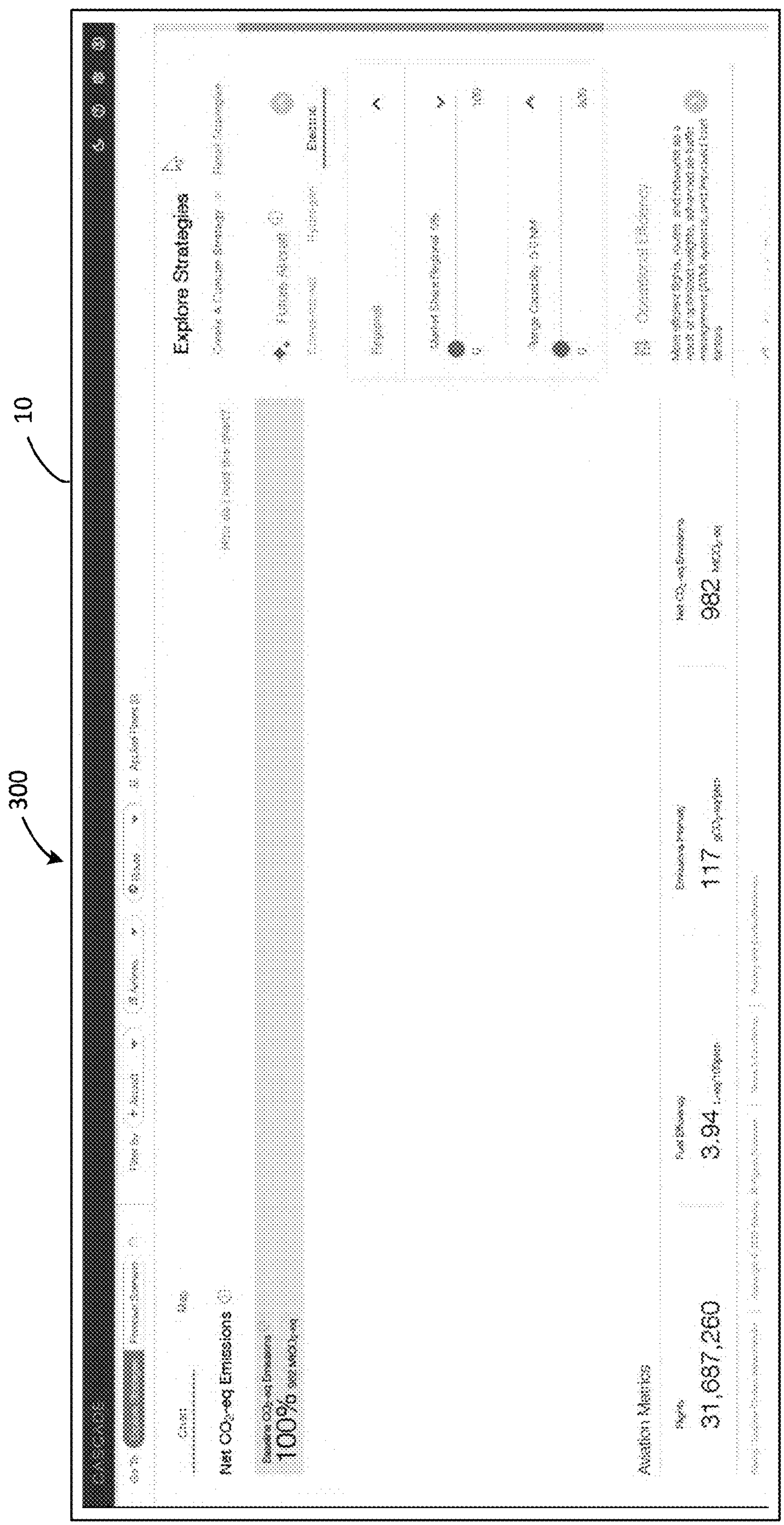

300
10
Explore Strategies
Net CO₂-eq Emissions
100%
Aviation Metrics
31,687,260
3.94
117
982

FIG. 27H

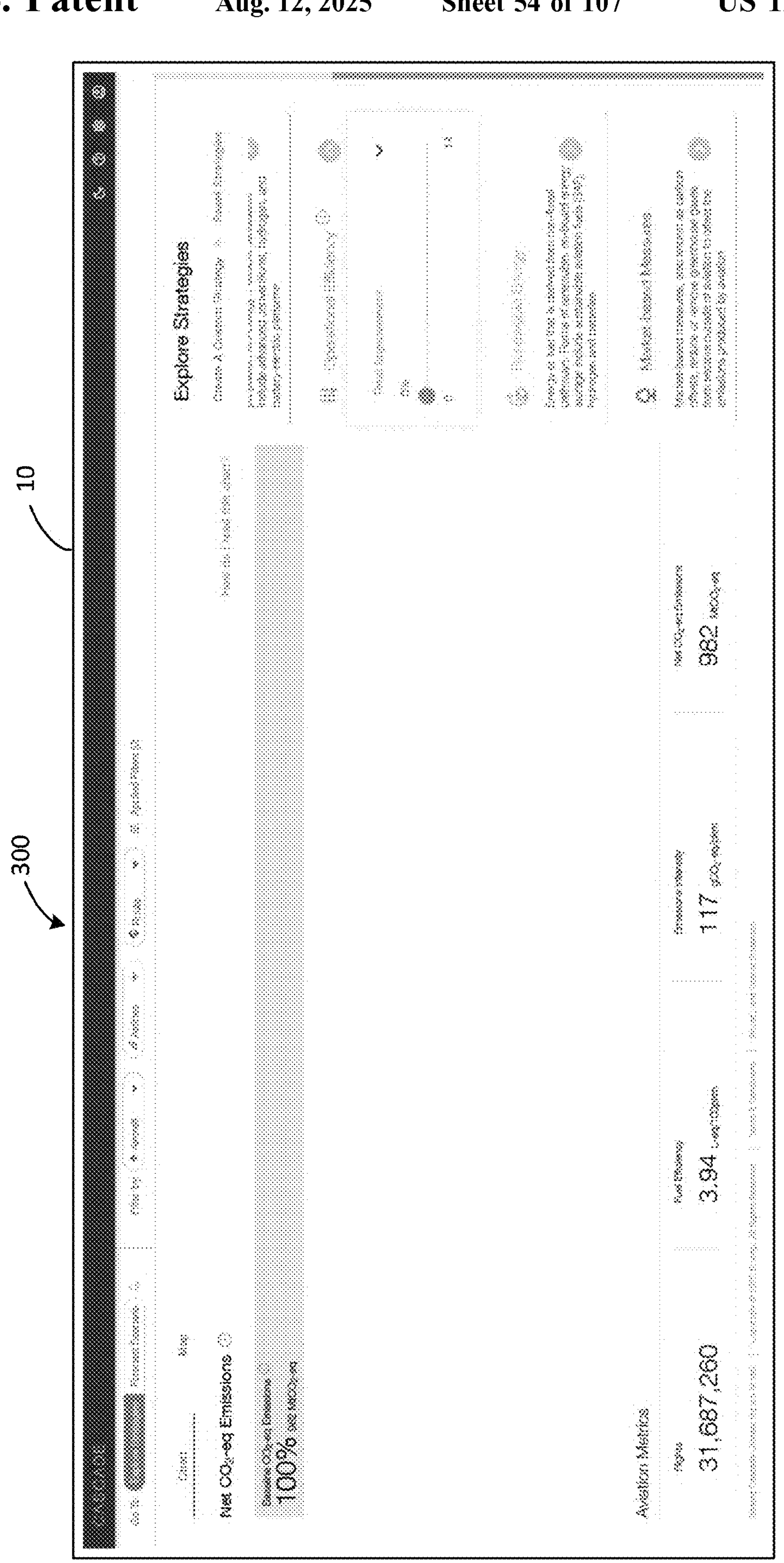

300
10
Net CO_2-eq Emissions
100%
Explore Strategies
Aviation Metrics
31,687,260
3.94
117
982

FIG. 28A

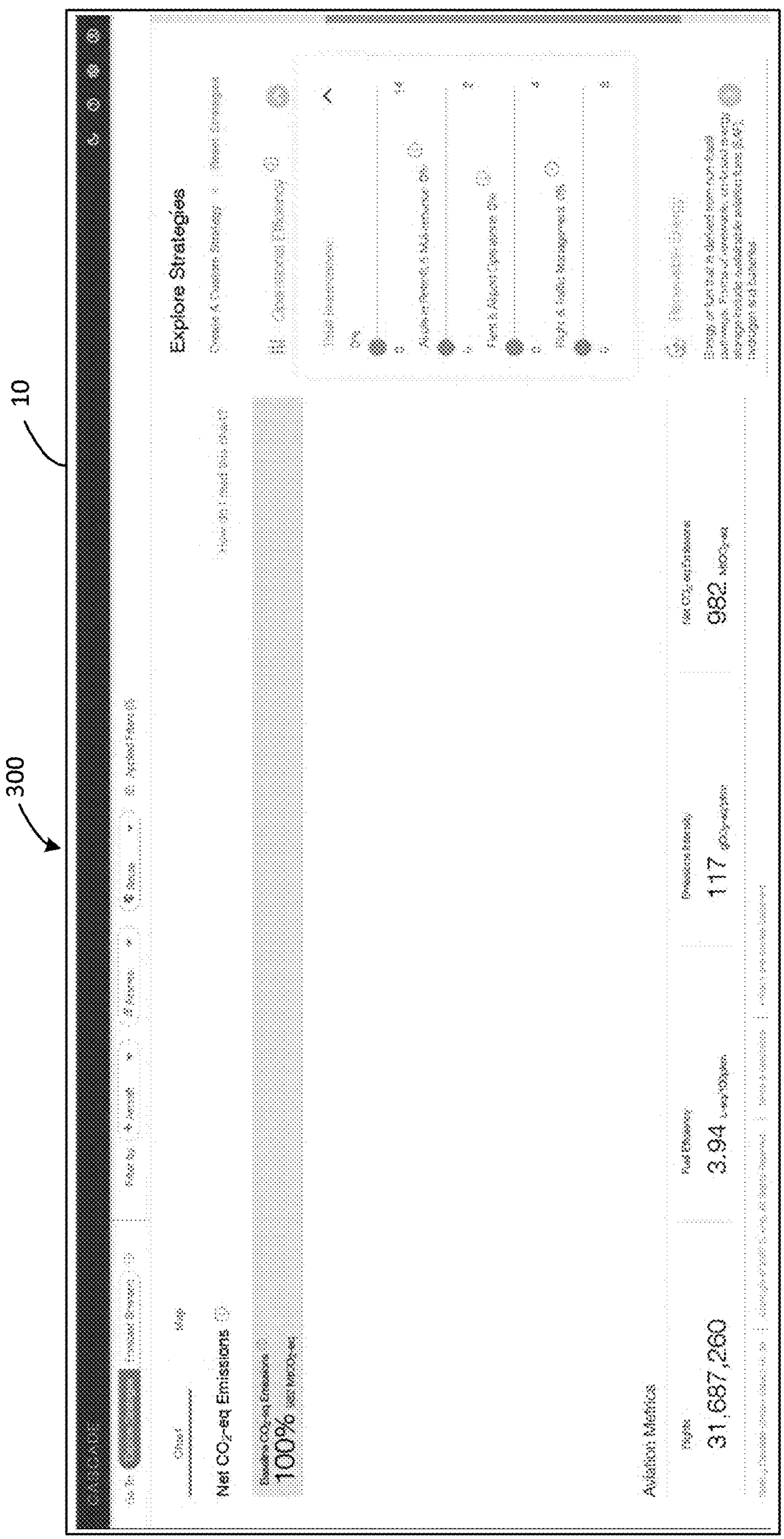

300
10
Explore Strategies
Net CO2-eq Emissions
100%
Aviation Metrics
31,687,260
3.94
117
982

FIG. 28B

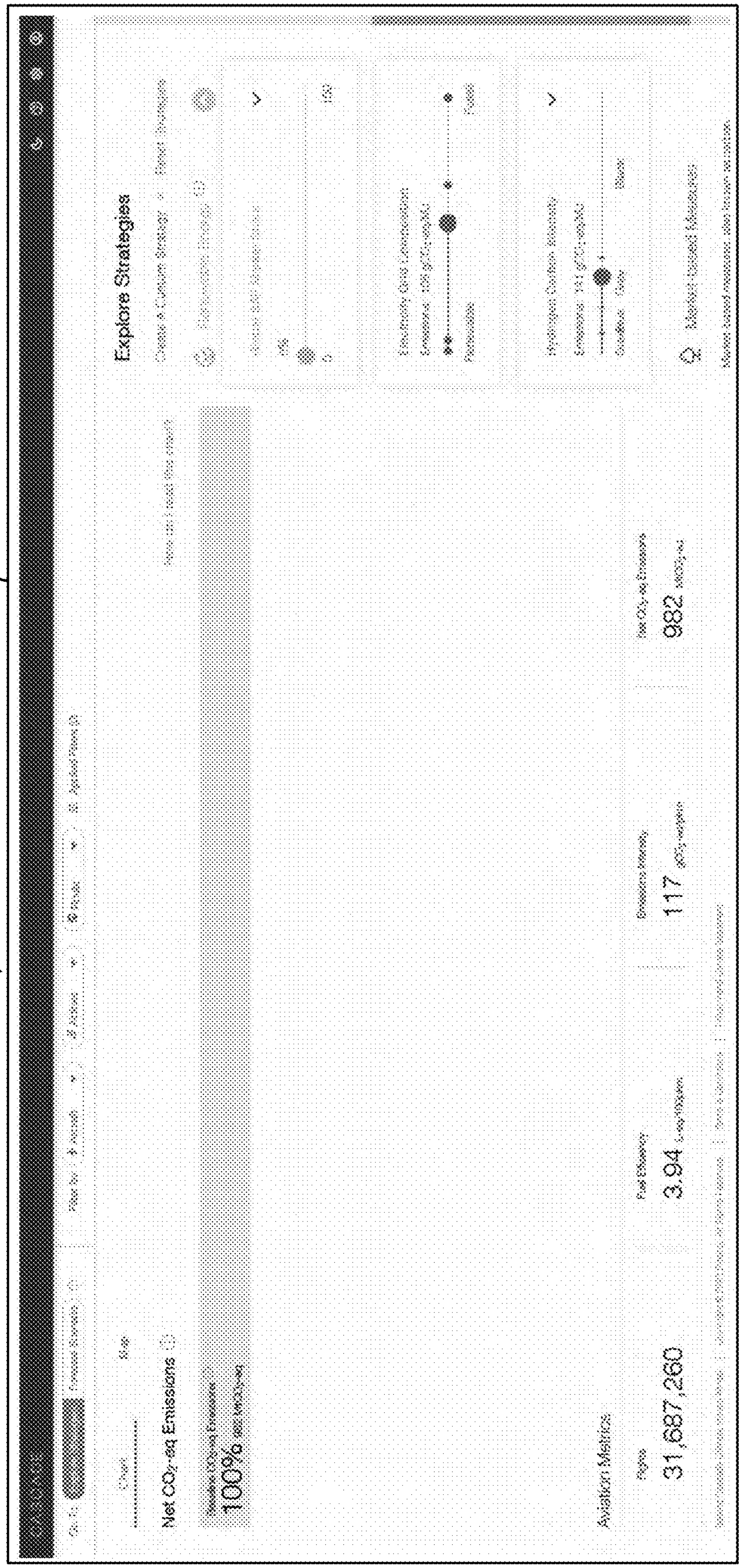

300
10
Explore Strategies
Net CO2-eq Emissions
100%
Aviation Metrics
31,687,260
3.94
117
982

FIG. 29A

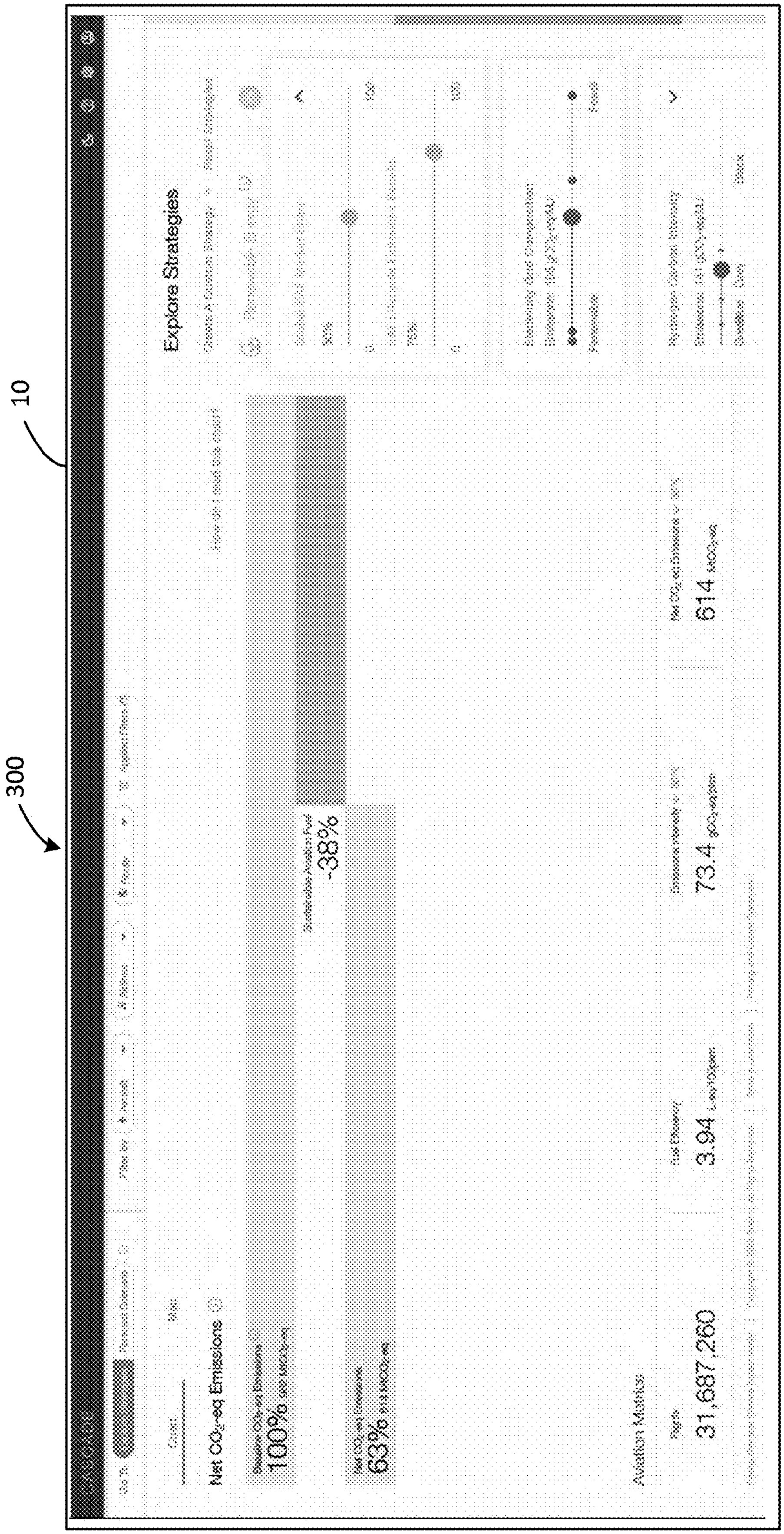

300
10
Explore Strategies
Net CO2-eq Emissions
100%
63%
-38%
Aviation Metrics
31,687,260
3.94
73.4
614

FIG. 29B

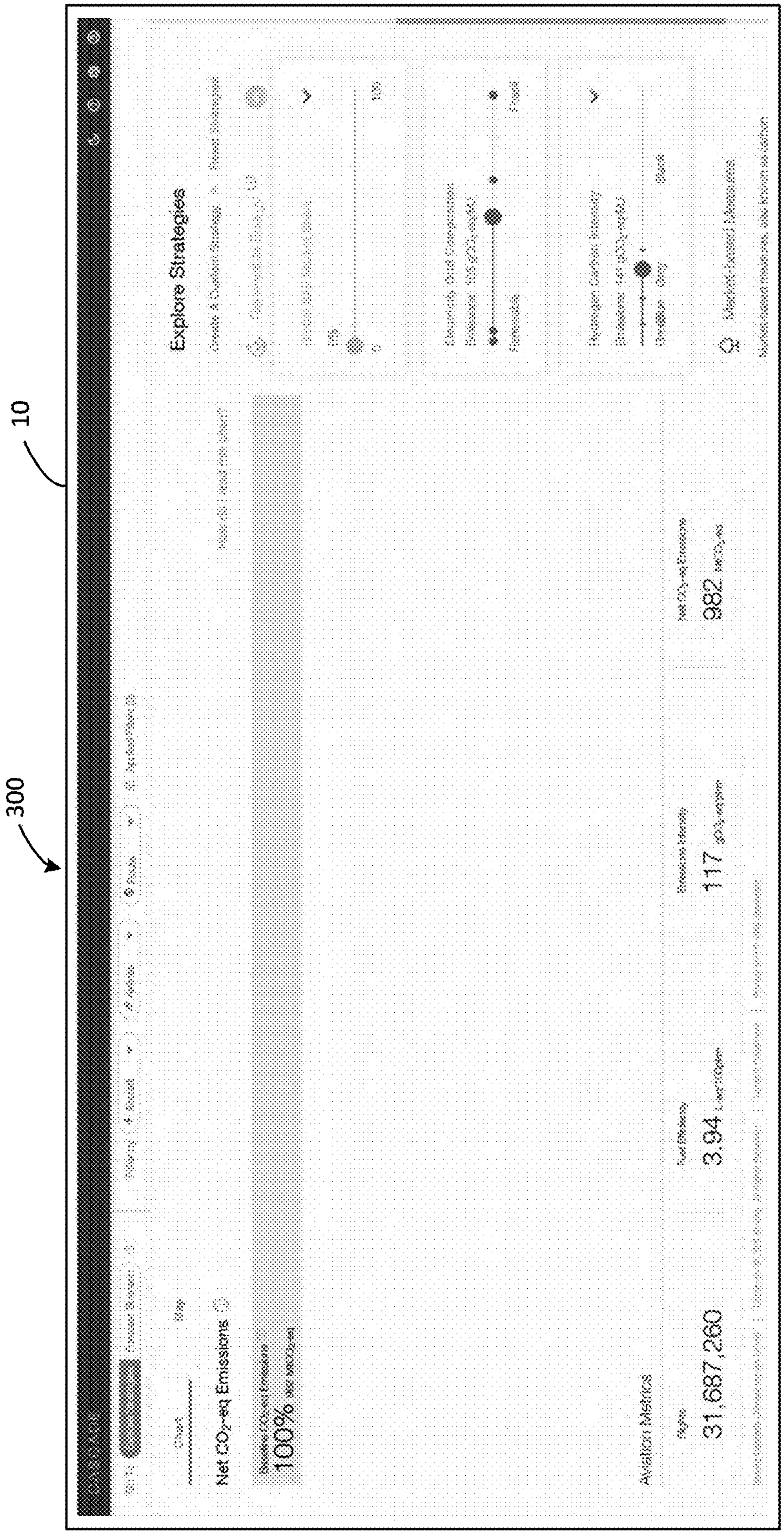

300
10
Net CO_2-eq Emissions
100%
Aviation Metrics
31,687,260
3.94
117
982
Explore Strategies

FIG. 29C

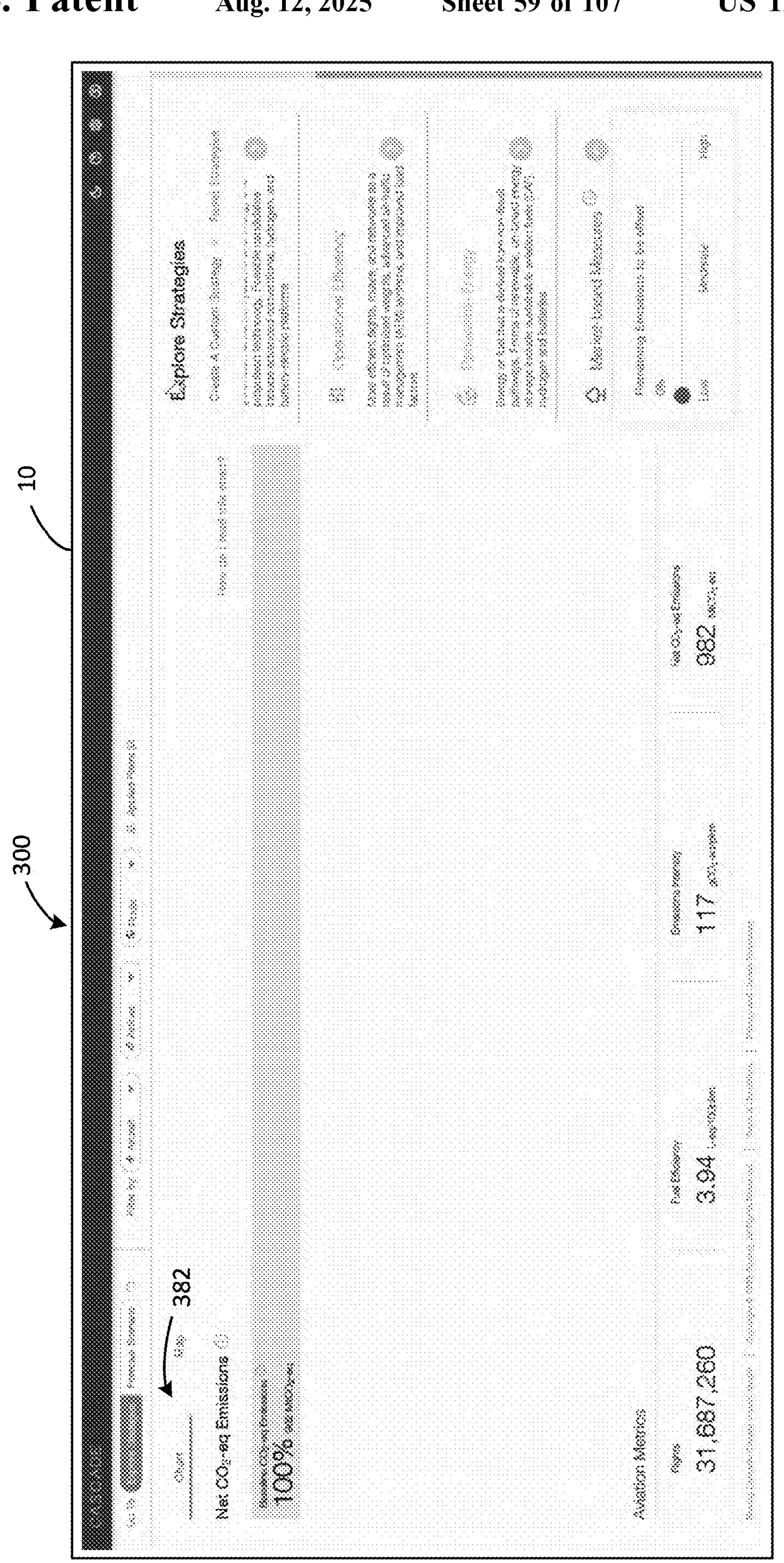

300
10
382
Explore Strategies
Net CO₂-eq Emissions
100%
Aviation Metrics
31,687,260
3.94
117
982

FIG. 30A

300

10

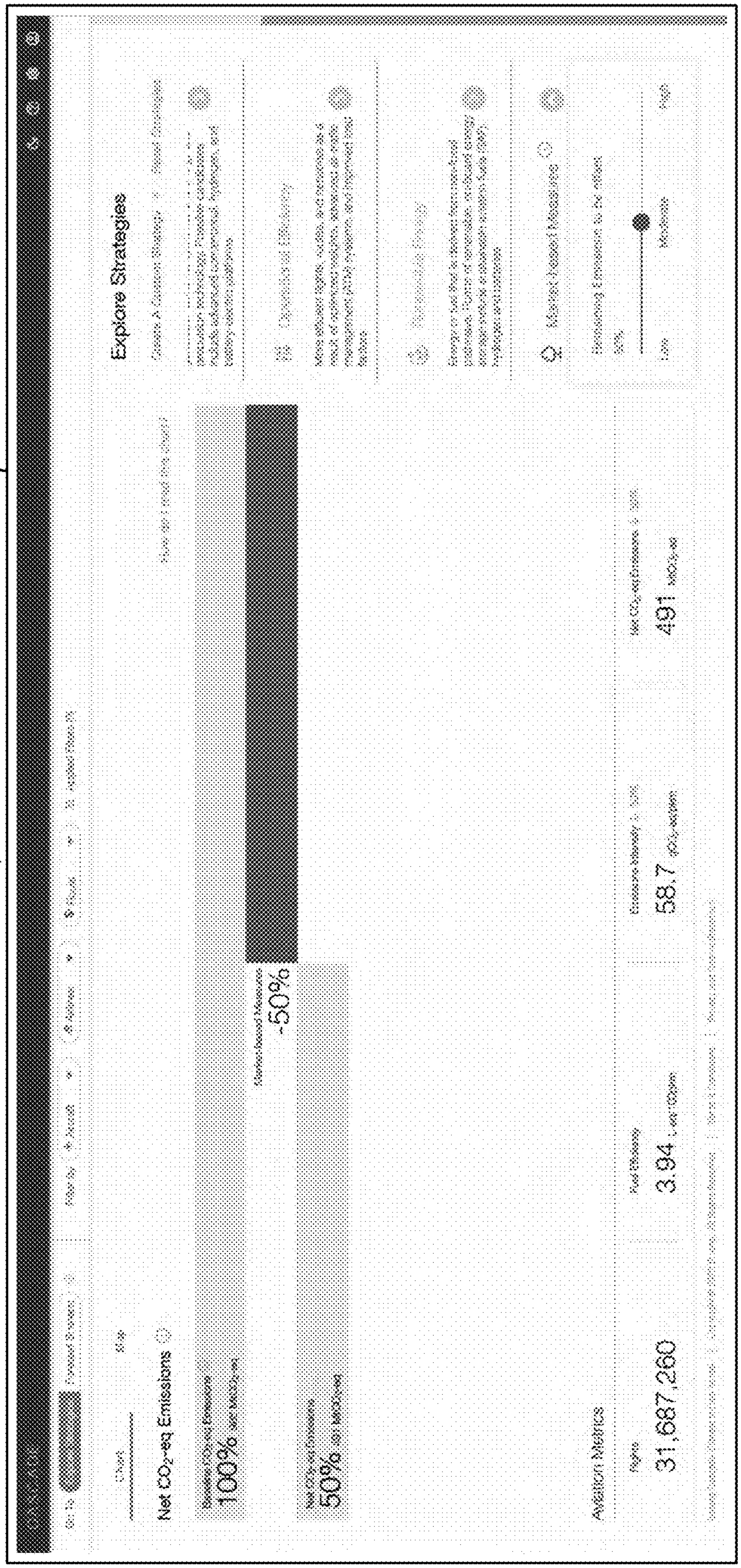


FIG. 30B

300

10

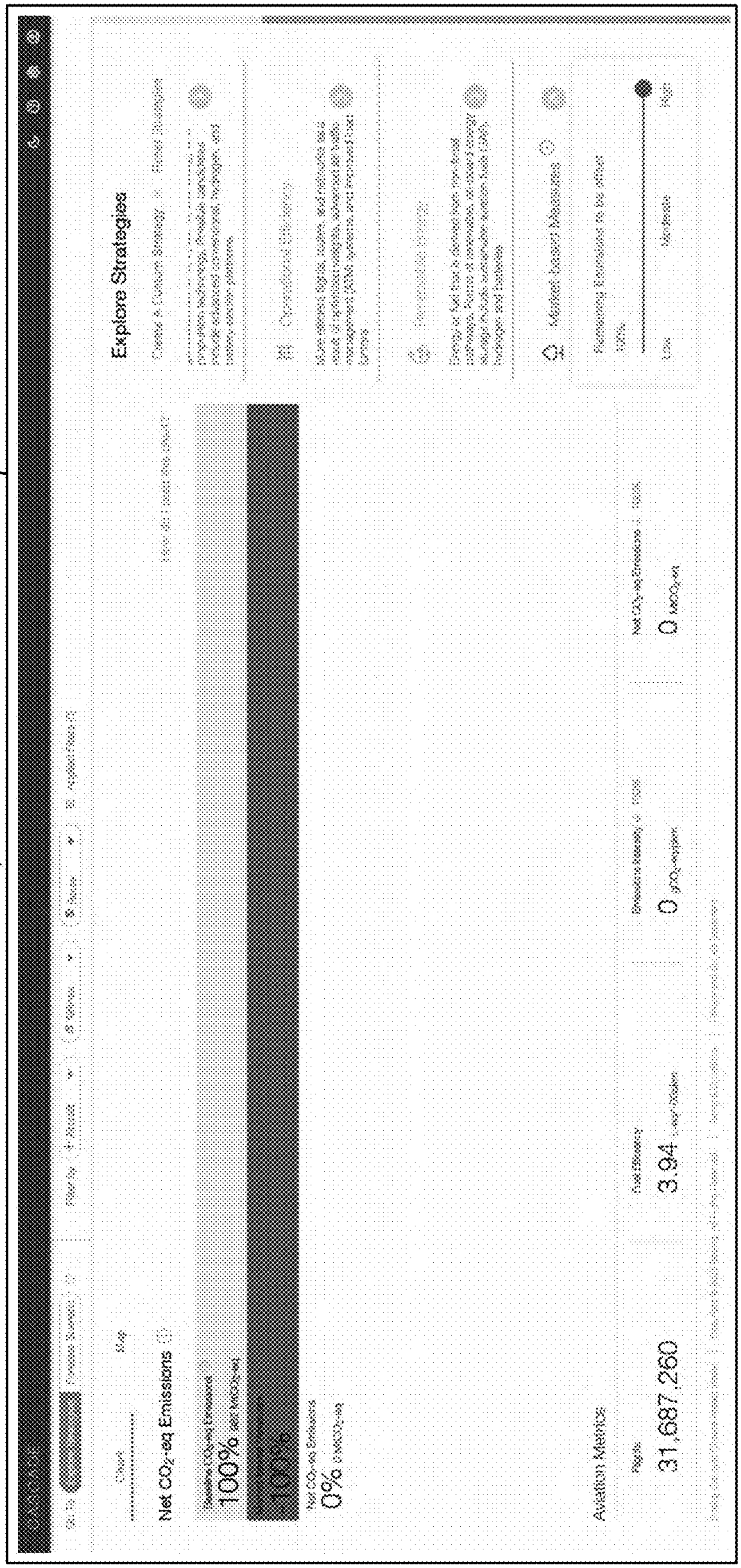
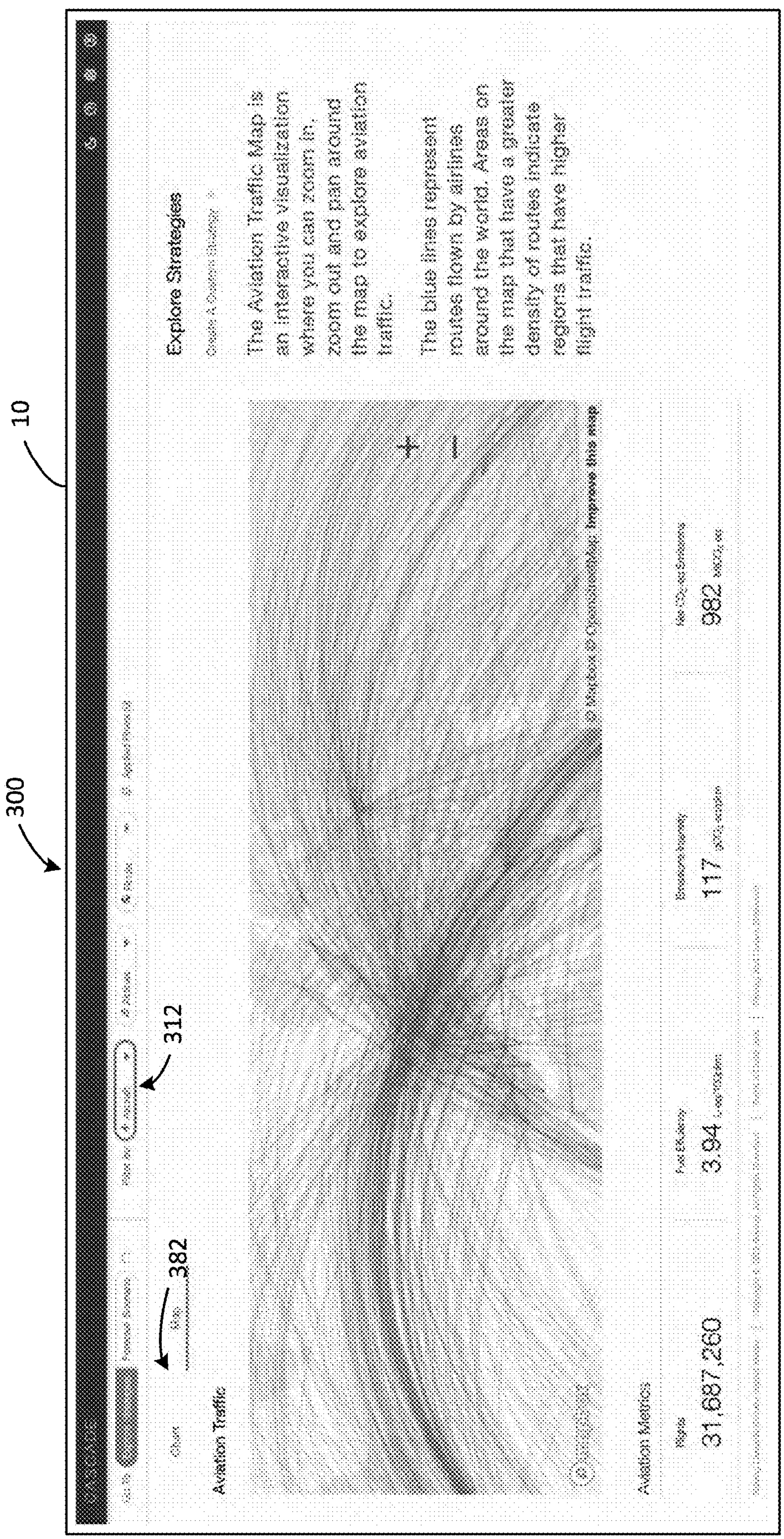


FIG. 30C



300
10
312
382
Aviation Traffic
Explore Strategies
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
Improve this map
Aviation Metrics
31,687,260
3.94
117
982

FIG. 31A

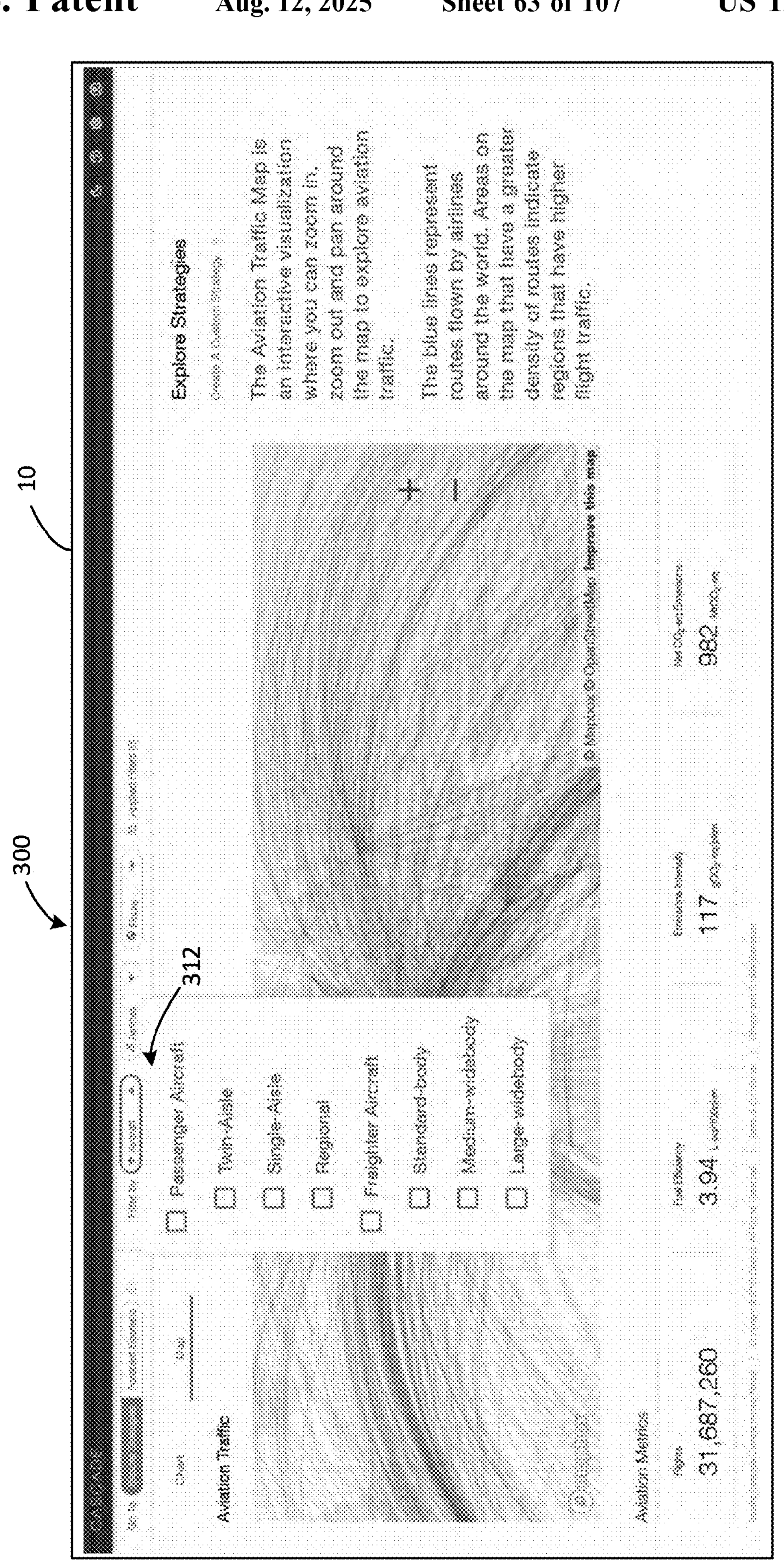

10
300
312
Aviation Traffic
Passenger Aircraft
Twin-Aisle
Single-Aisle
Regional
Freighter Aircraft
Standard-body
Medium-widebody
Large-widebody
Explore Strategies
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
Aviation Metrics
31,687,260
3.94
117
982

FIG. 31B

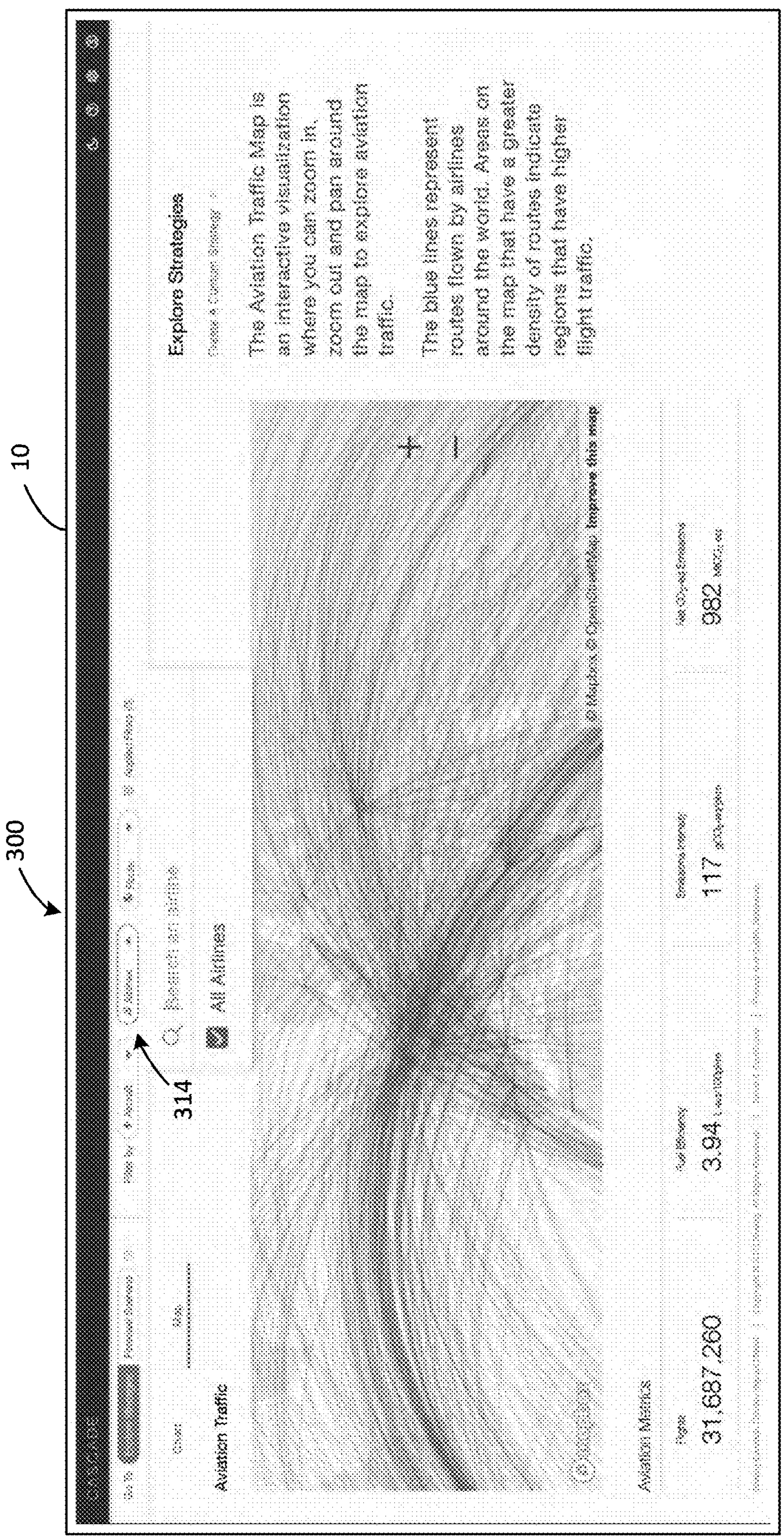

300
10
314
Aviation Traffic
Search an airline
All Airlines
Explore Strategies
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
Aviation Metrics
31,687,260
3.94
117
982

FIG. 32A

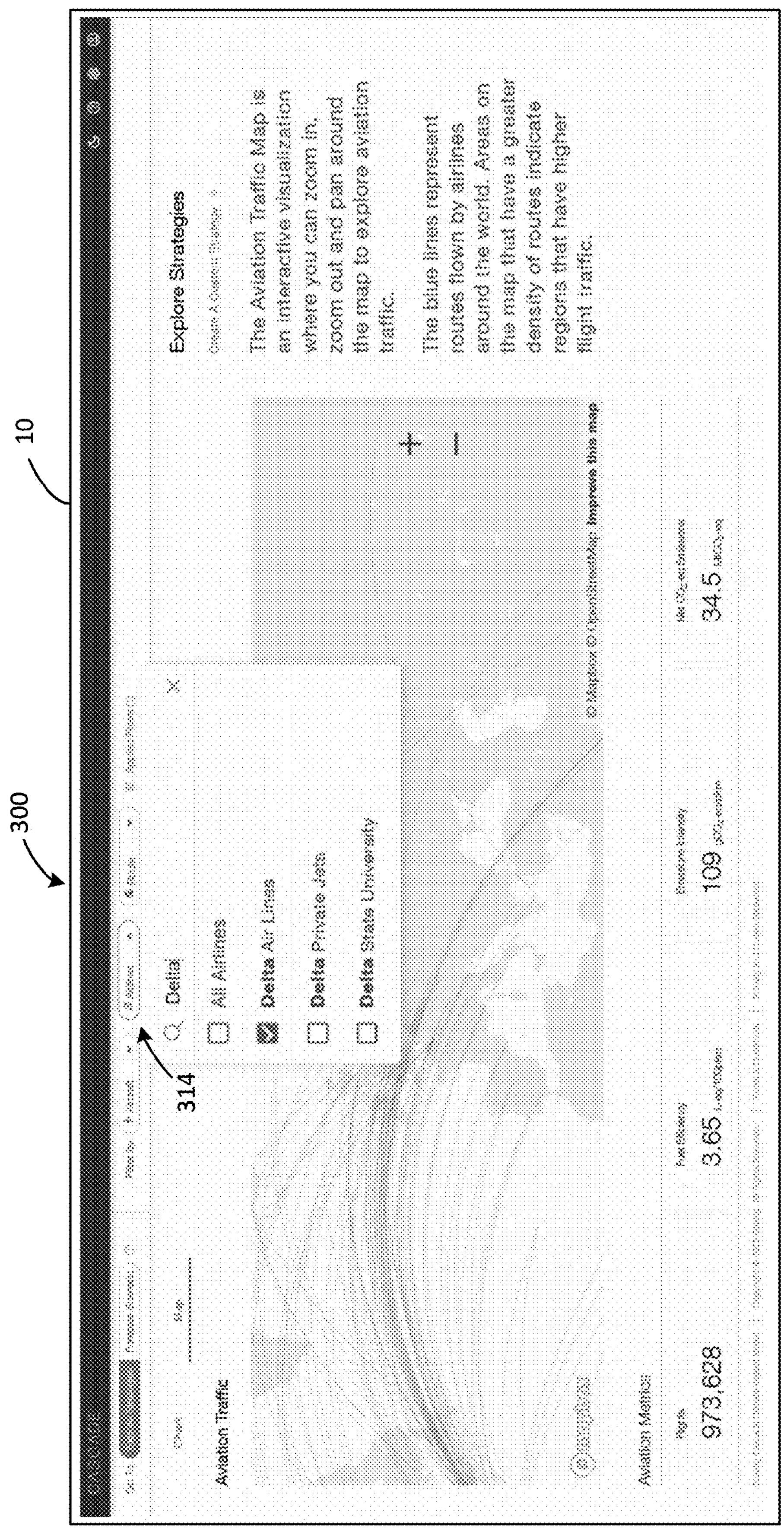

300
10
314
Aviation Traffic
Delta
All Airlines
Delta Air Lines
Delta Private Jets
Delta State University
Explore Strategies
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
Improve this map
Aviation Metrics
973,628
3.65
109
34.5

FIG. 32B

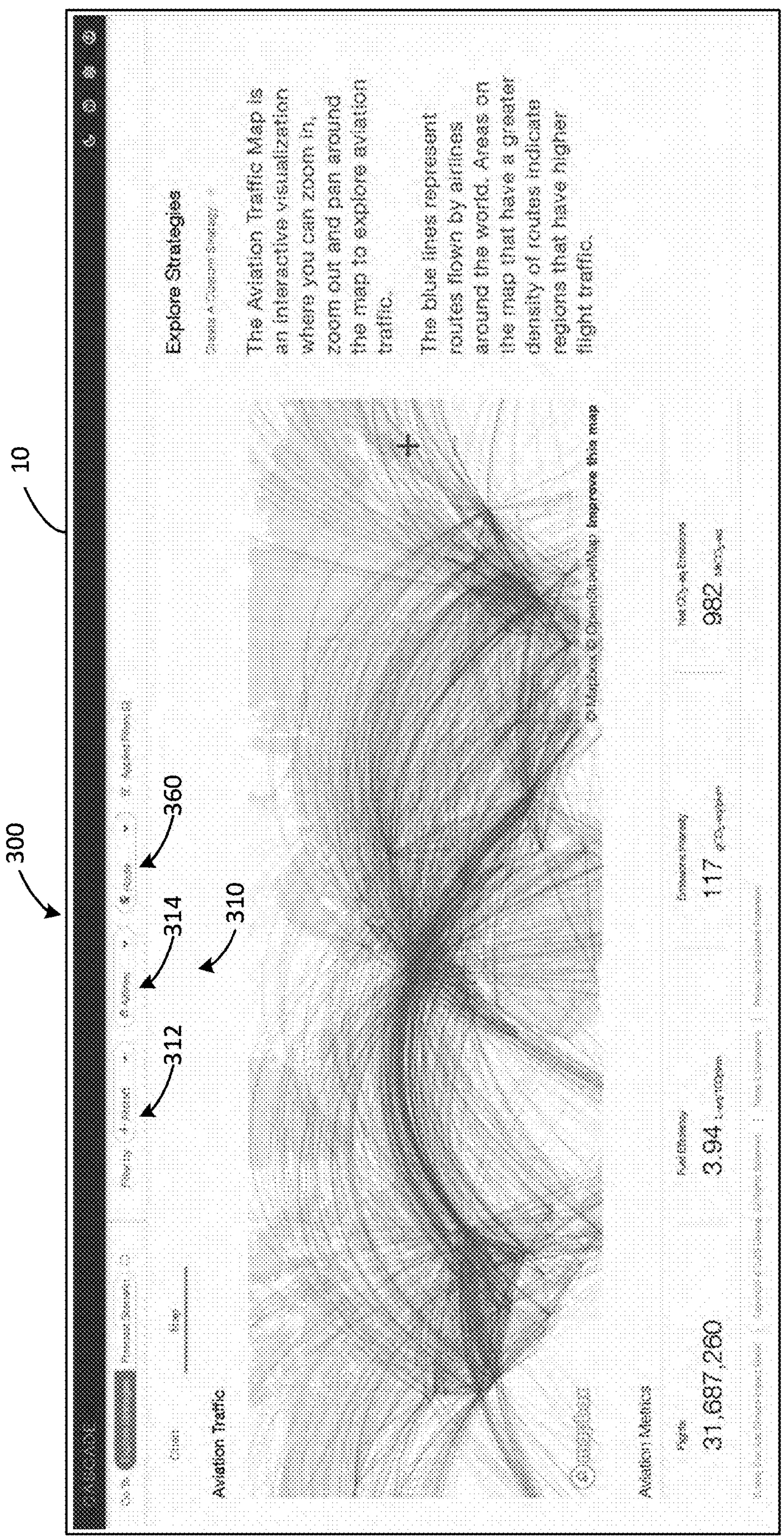
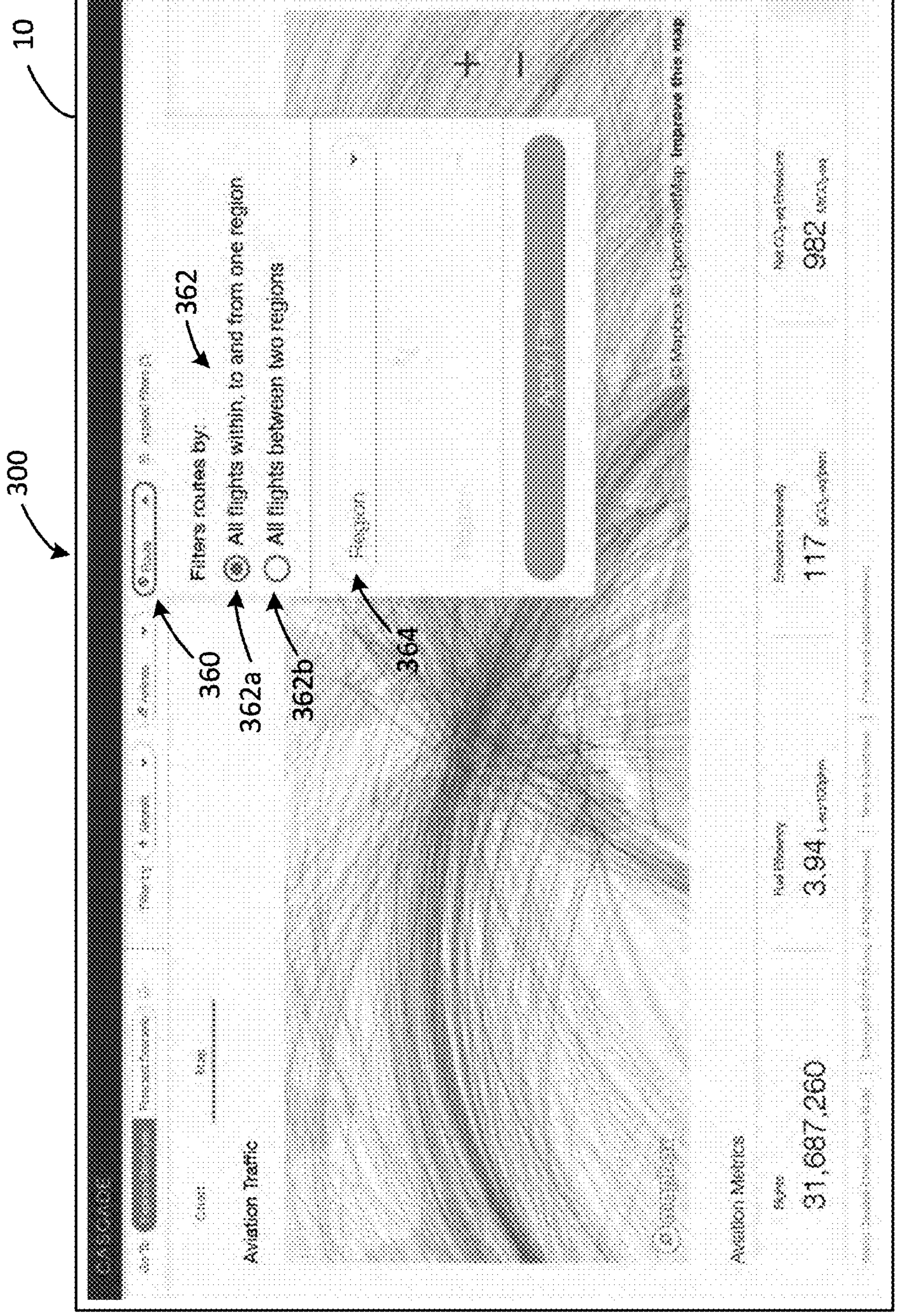

10
300
312
314
310
360
Explore Strategies
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
Aviation Traffic
Improve this map
Aviation Metrics
31,687,260
3.94
117
982

FIG. 33A



300
10
360
362
362a
362b
364
Aviation Traffic
Filters routes by:
All flights within, to and from one region
All flights between two regions
Region
Explore Strategies
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
New version is available
UPDATE
Aviation Metrics
31,687,260
3.94
117
982

FIG. 33B

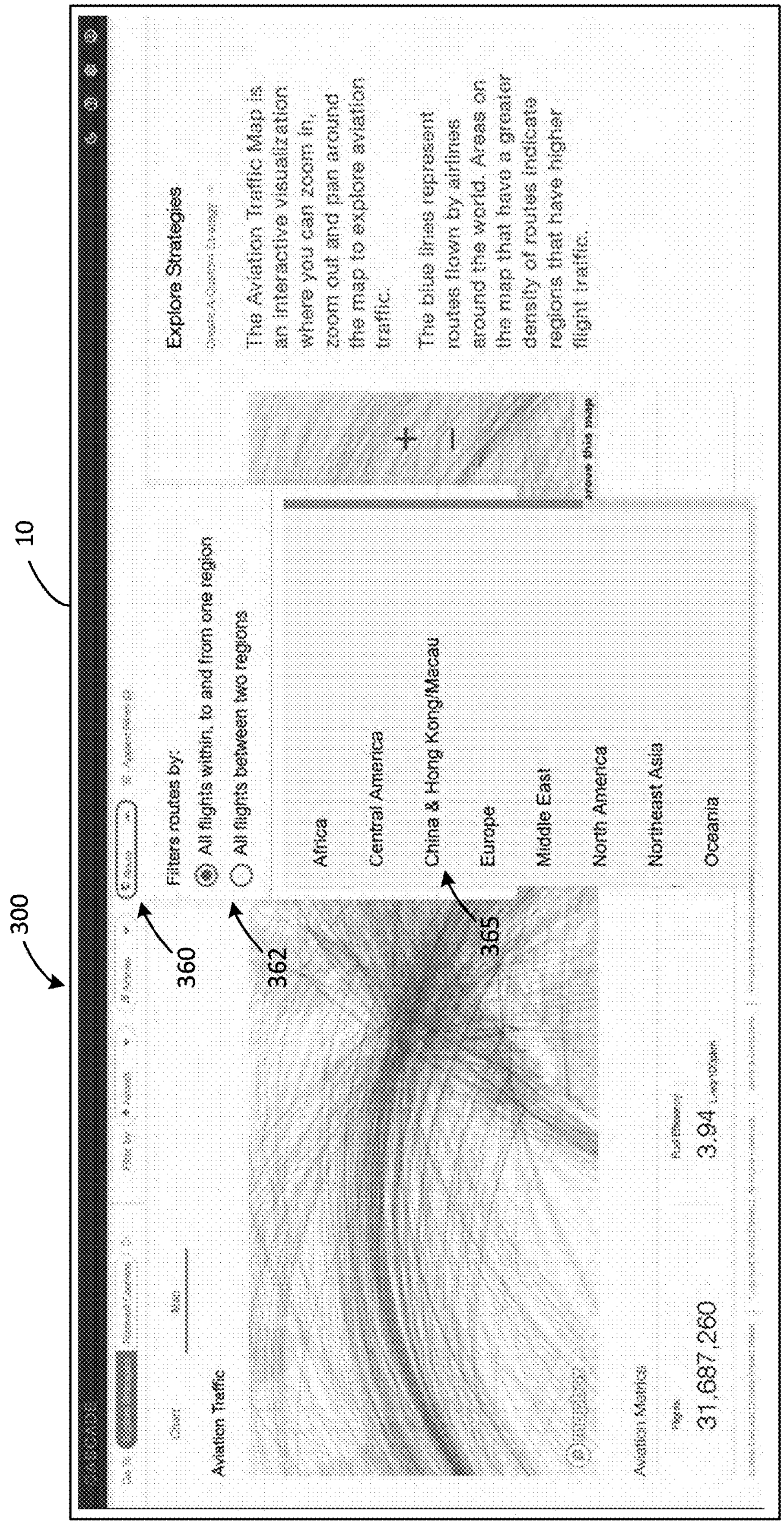

300
10
Aviation Traffic
Filters routes by:
All flights within, to and from one region
All flights between two regions
360
362
Africa
Central America
China & Hong Kong/Macau
Europe
Middle East
North America
Northeast Asia
Oceania
365
Explore Strategies
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
+
−
Aviation Metrics
31,687,260
3.94

FIG. 33C

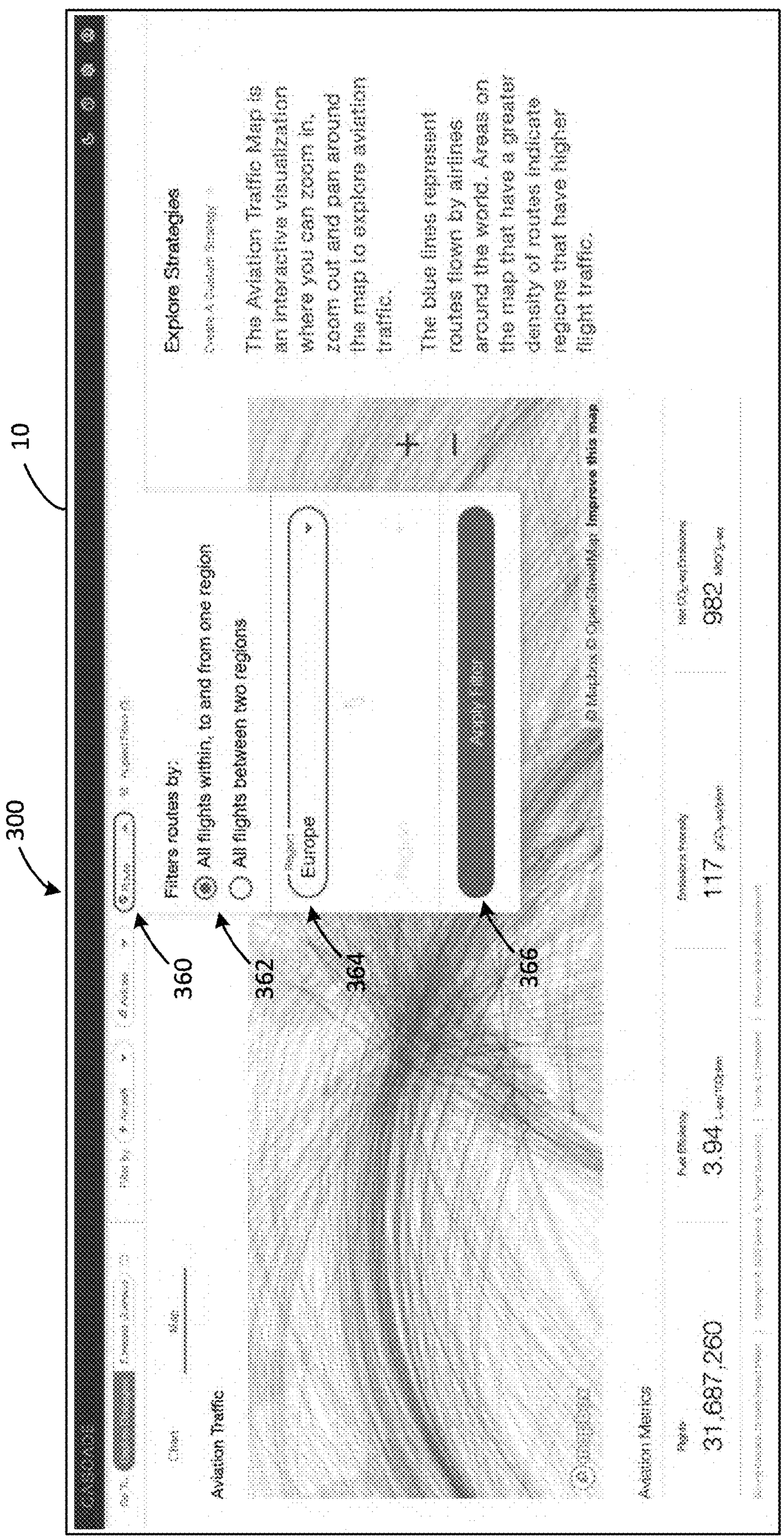

10
300
360
362
364
366
Aviation Traffic
Filters routes by:
All flights within, to and from one region
All flights between two regions
Europe
Explore Strategies
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
Improve this map
Aviation Metrics
31,687,260
3.94
117
982

FIG. 33D

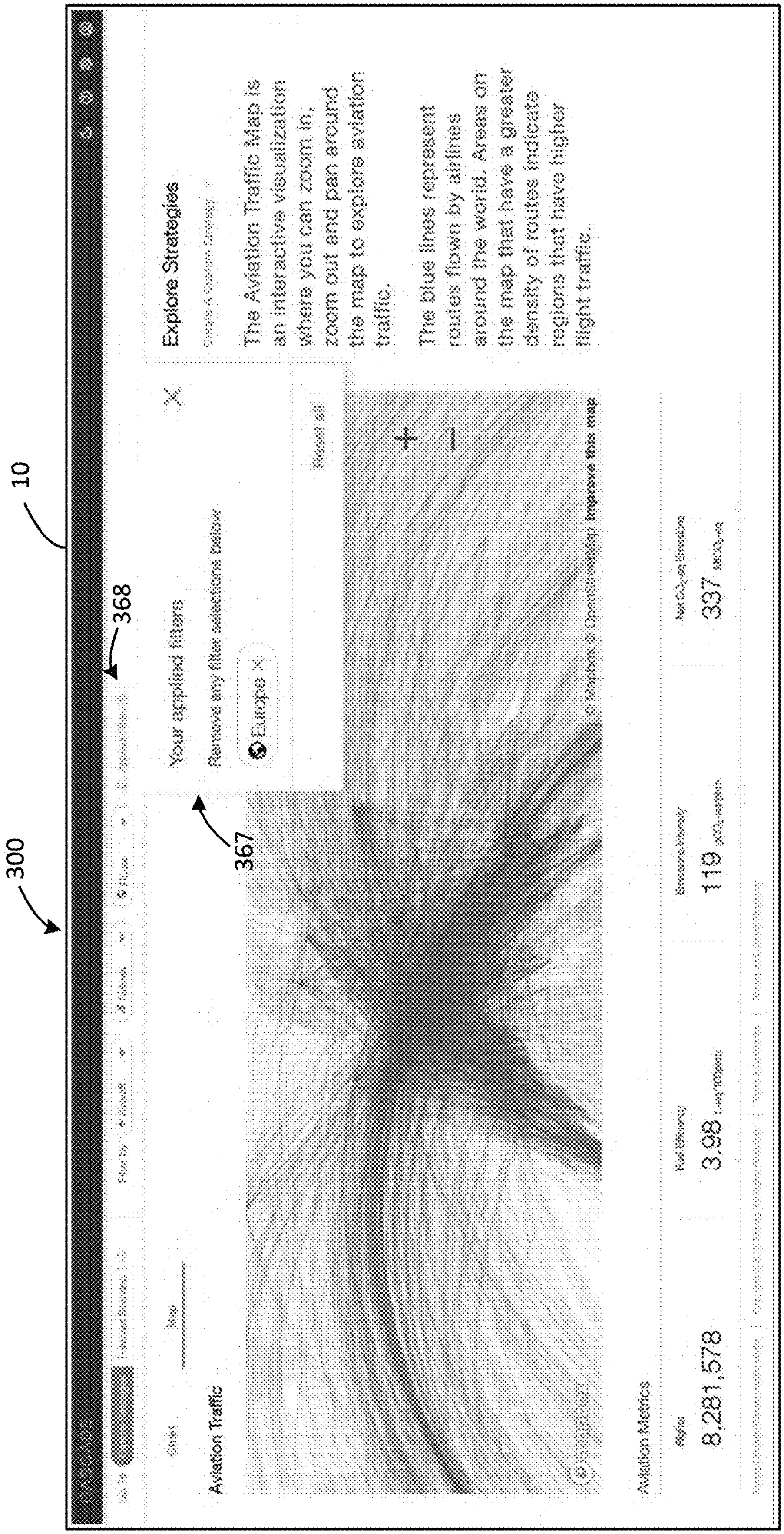

10
300
367
368
Explore Strategies
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
Your applied filters
Remove any filter selections below
Europe ×
Reset all
Aviation Traffic
Aviation Metrics
8,281,578
3.98
119
337

FIG. 33E

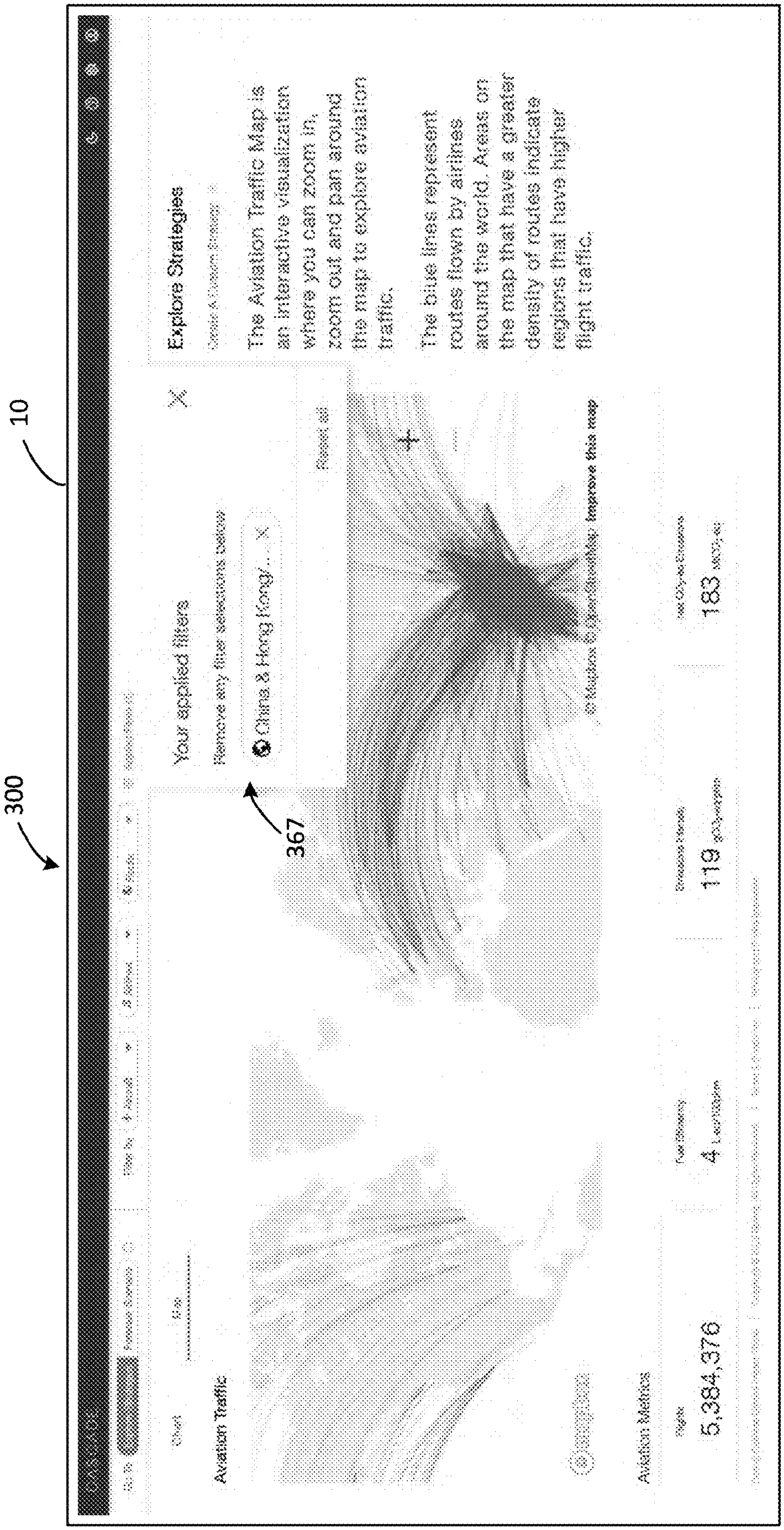

300
10
367
Aviation Traffic
Explore Strategies
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
Your applied filters
China & Hong Kong/...
Reset all
Improve this map
Aviation Metrics
5,384,376
4
119
183

FIG. 33F

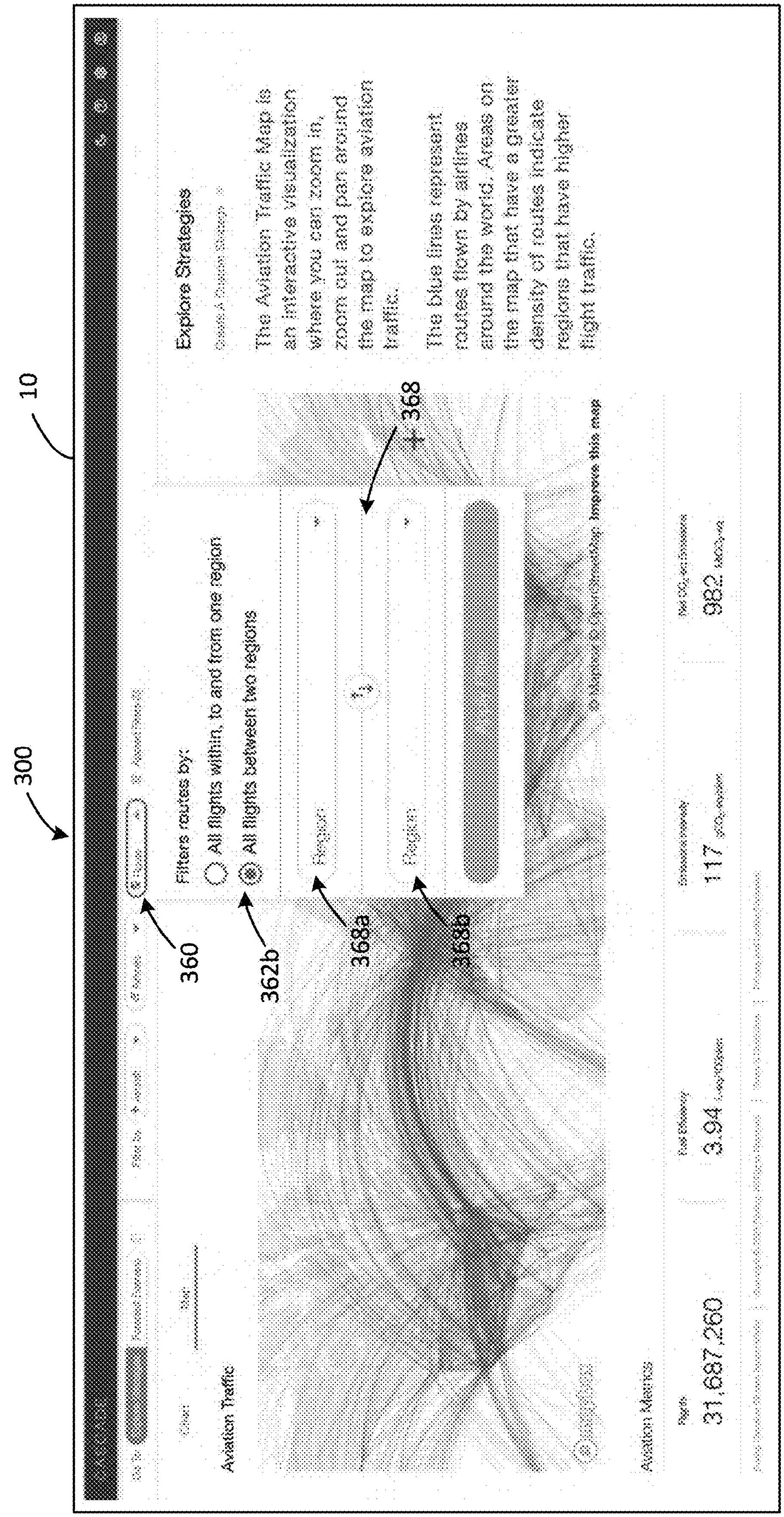

10
300
360
362b
368a
368b
368
Aviation Traffic
Filters routes by:
All flights within, to and from one region
All flights between two regions
Region
Region
Explore Strategies
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
Improve this map
Aviation Metrics
31,687,260
3.94
117
982

FIG. 33G

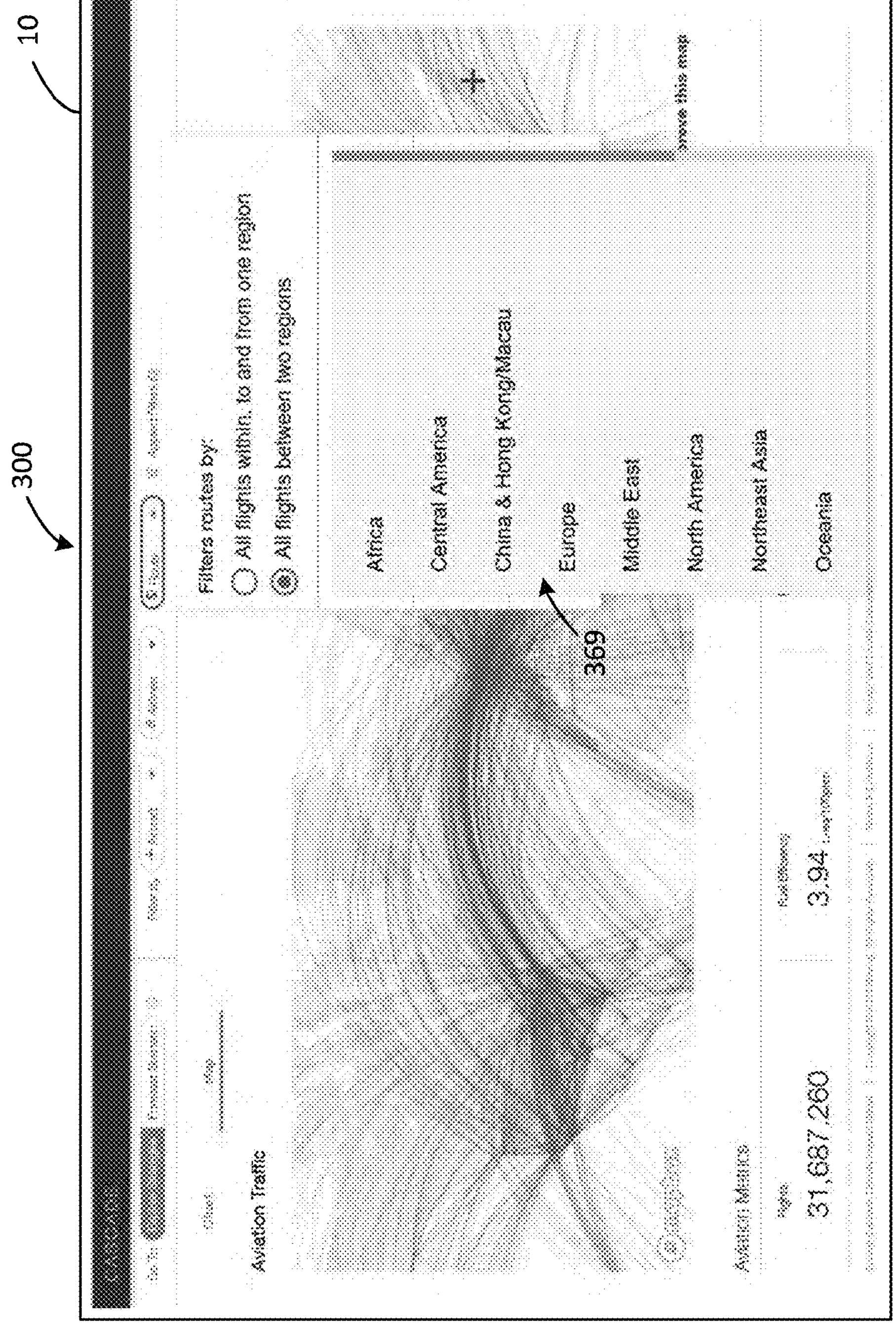

300
10
369
Aviation Traffic
Aviation Metrics
31,687,260
3.94
Filters routes by:
All flights within, to and from one region
All flights between two regions
Africa
Central America
China & Hong Kong/Macau
Europe
Middle East
North America
Northeast Asia
Oceania
Explore Strategies
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.

FIG. 33H

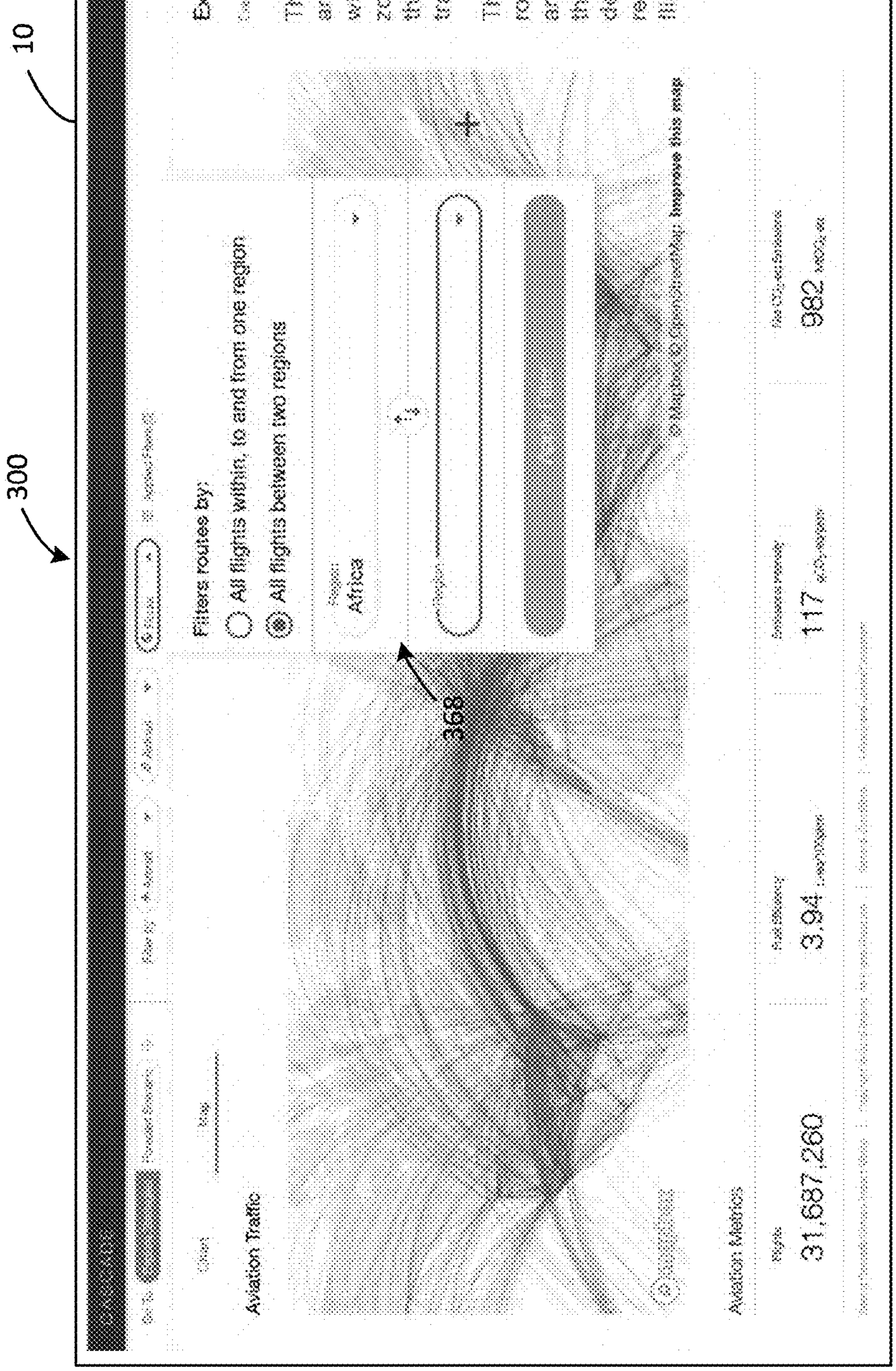

300
10
Aviation Traffic
Filters routes by:
All flights within, to and from one region
All flights between two regions
Africa
368
Improve this map
Explore Strategies
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
Aviation Metrics
31,687,260
3.94
117
982

FIG. 33I

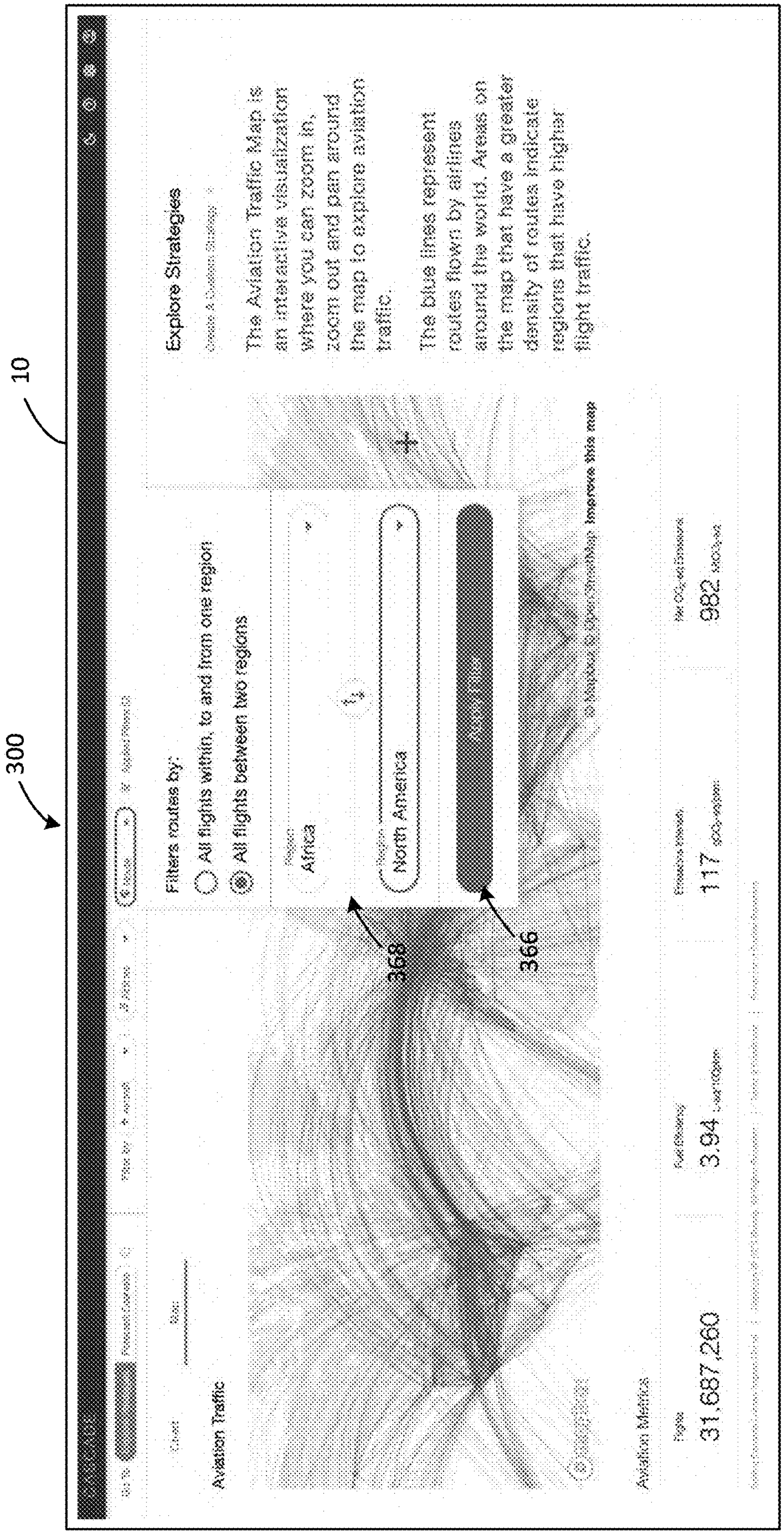
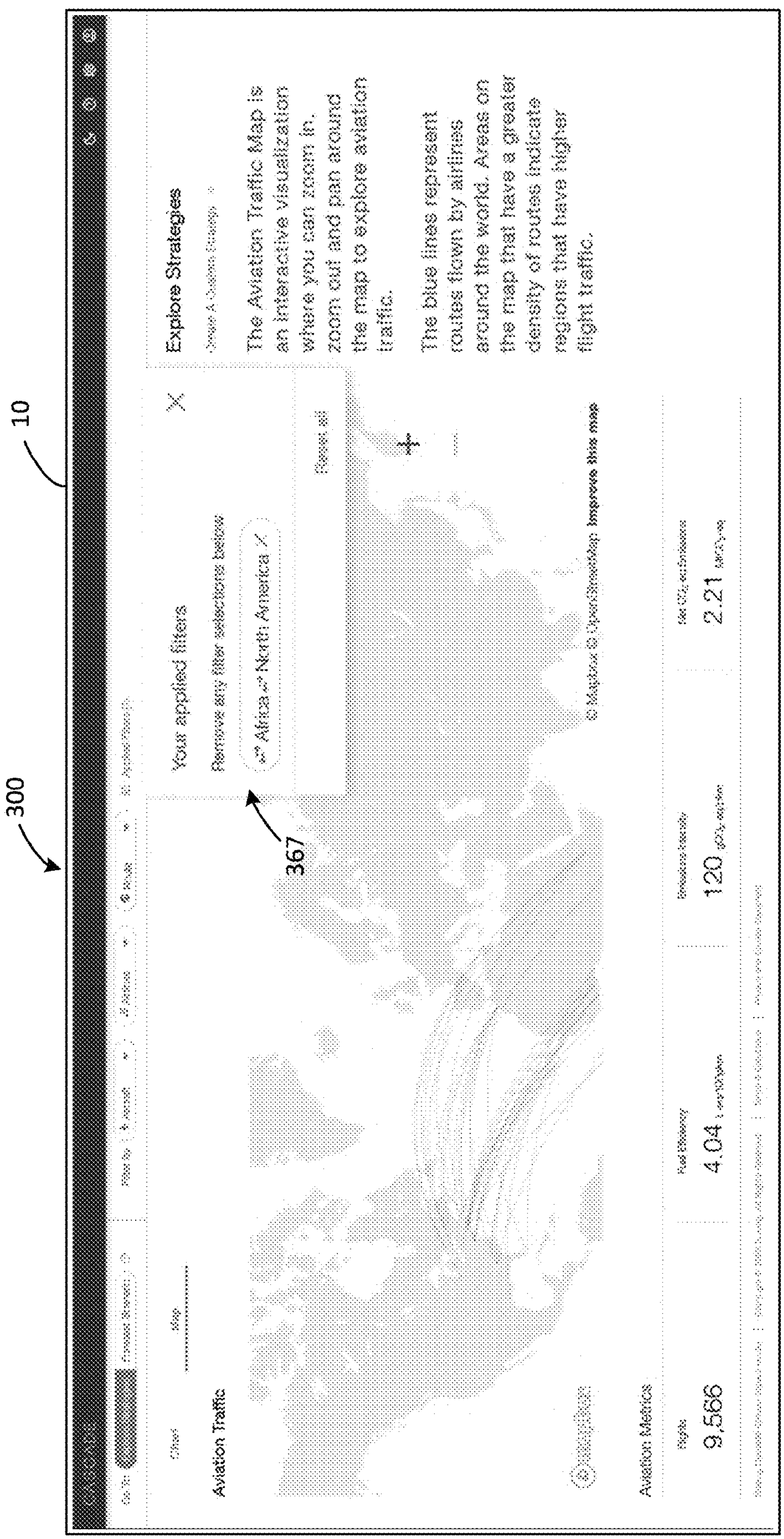

300
10
Aviation Traffic
Filters routes by:
All flights within, to and from one region
All flights between two regions
Africa
North America
368
366
Explore Strategies
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
Improve this map
Aviation Metrics
31,687,260
3.94
117
982

FIG. 33J



10
300
367
Aviation Traffic
Your applied filters
Remove any filter selections below
Africa → North America
Reset all
Explore Strategies
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
© Mapbox © OpenStreetMap Improve this map
Aviation Metrics
9,566
4.04
120
2.21

FIG. 33K

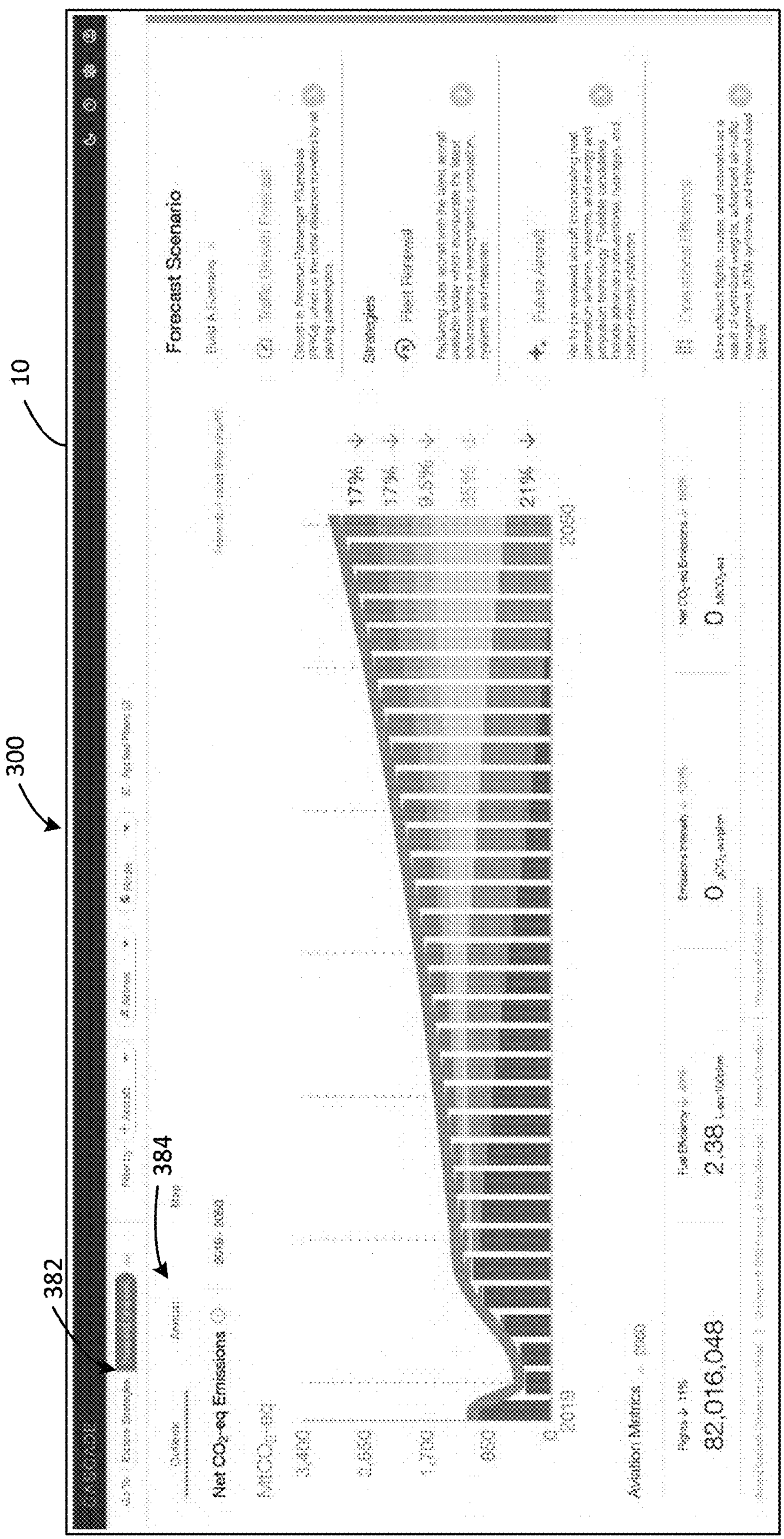

10
300
382
384
Forecast Scenario
Net CO2-eq Emissions
3,400
2,550
1,700
850
0
2019
2050
17%
17%
9.57%
21%
Aviation Metrics
82,016,048
2.38
0
0

FIG. 34A

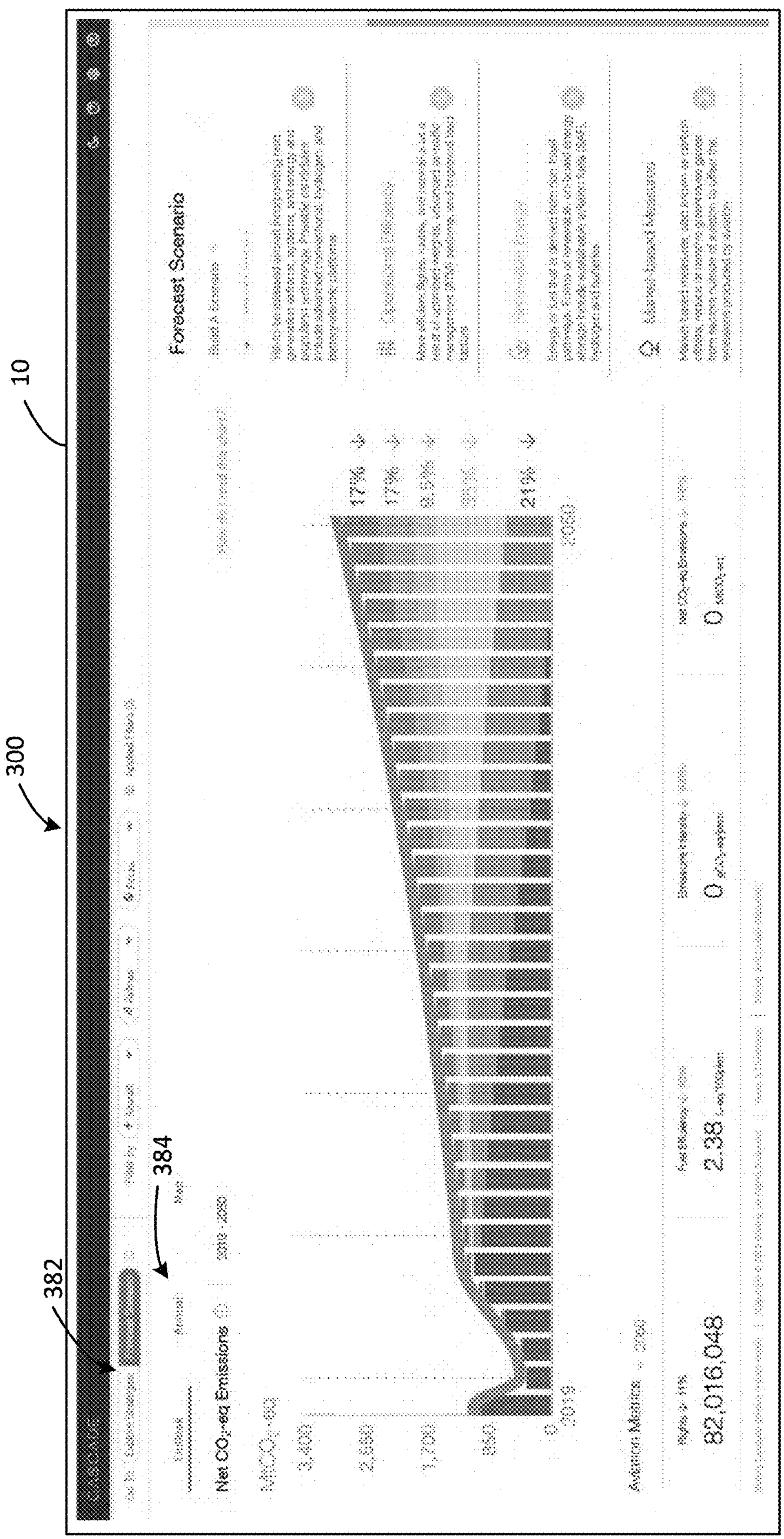

10
300
382
384
Forecast Scenario
Net CO2-eq Emissions
82,016,048
2.38
2019
2050

FIG. 34B

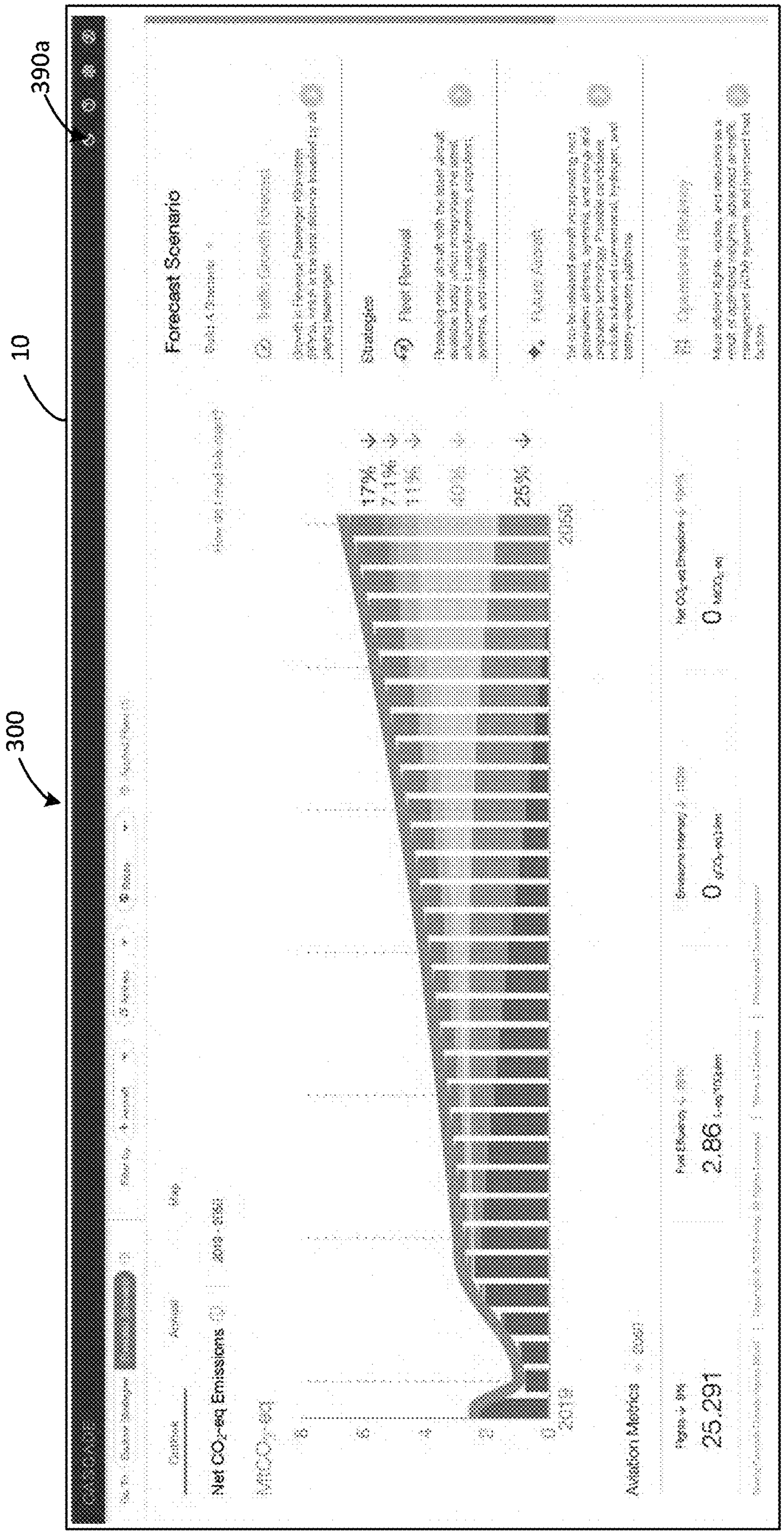

300
10
390a
Net CO₂-eq Emissions
Forecast Scenario
Strategies
Aviation Metrics
25,291
2.86
0
0
2019
2050
17%
25%

FIG. 35A

300 10 390b

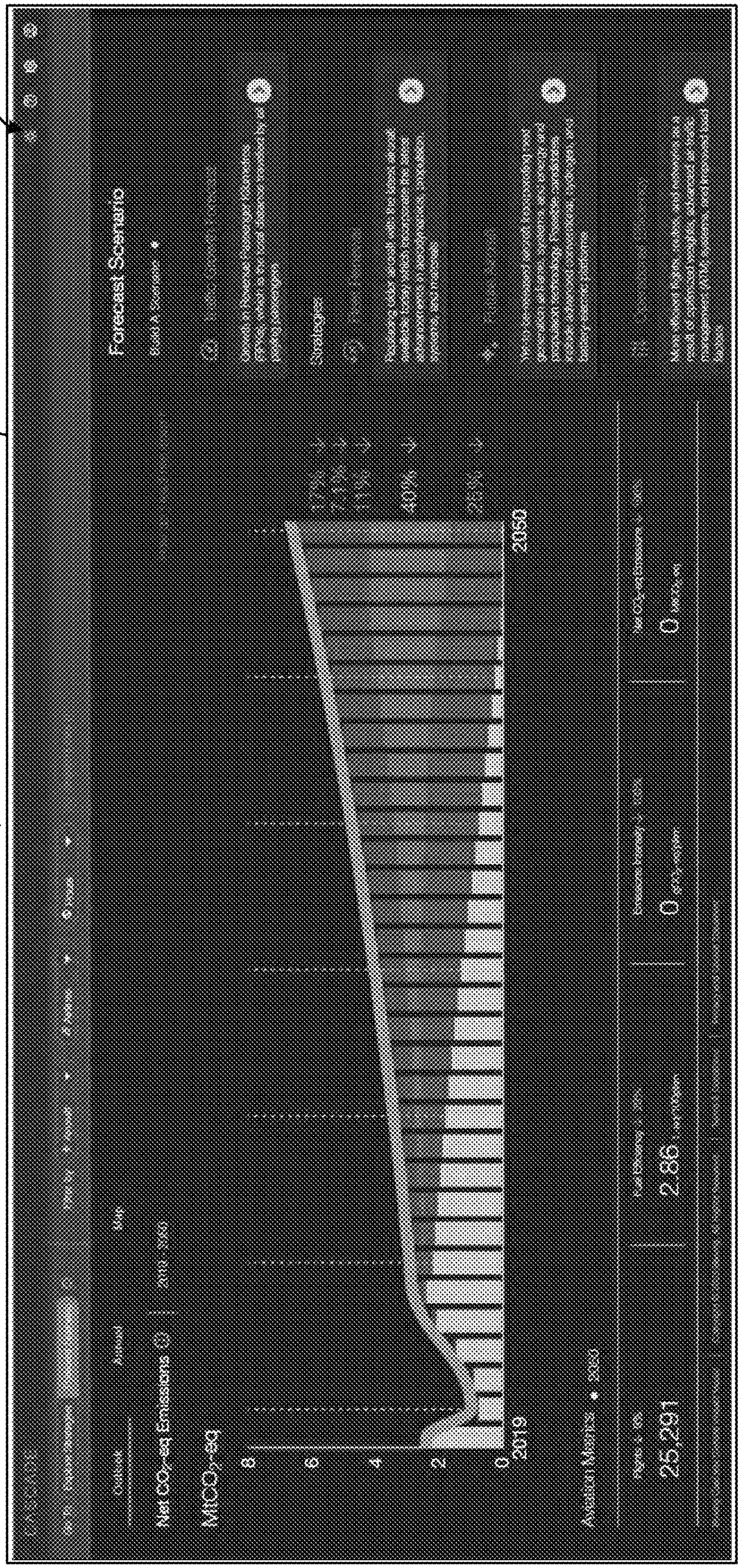


FIG. 35B

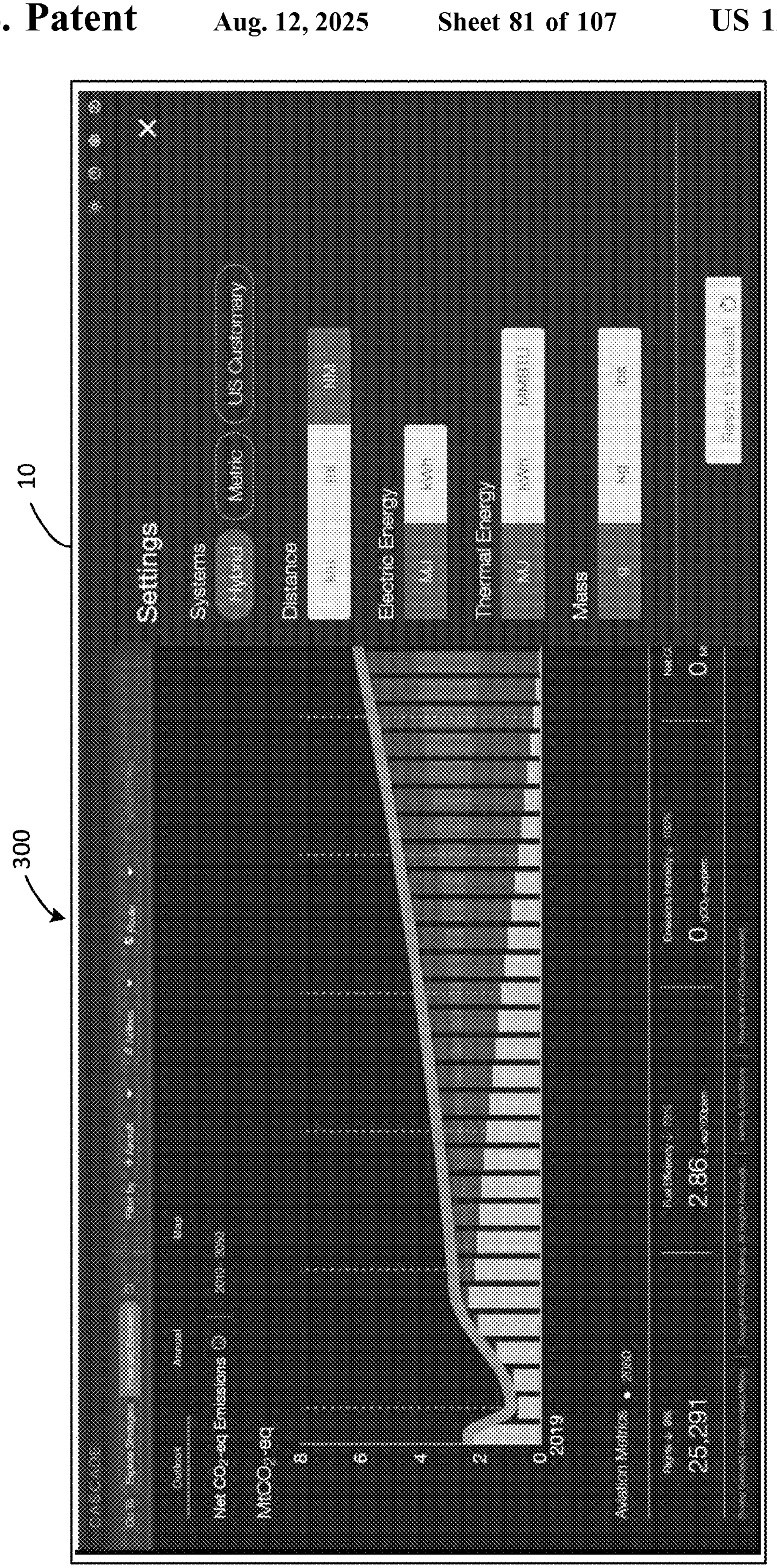

10
300
Settings
Systems
Metric
US Customary
Distance
Electric Energy
Thermal Energy
Mass
Net CO_2-eq Emissions
$MtCO_2$-eq
8
6
4
2
0
2019
Aviation Metrics
25,291
2.86
0
0

FIG. 35C

300

10

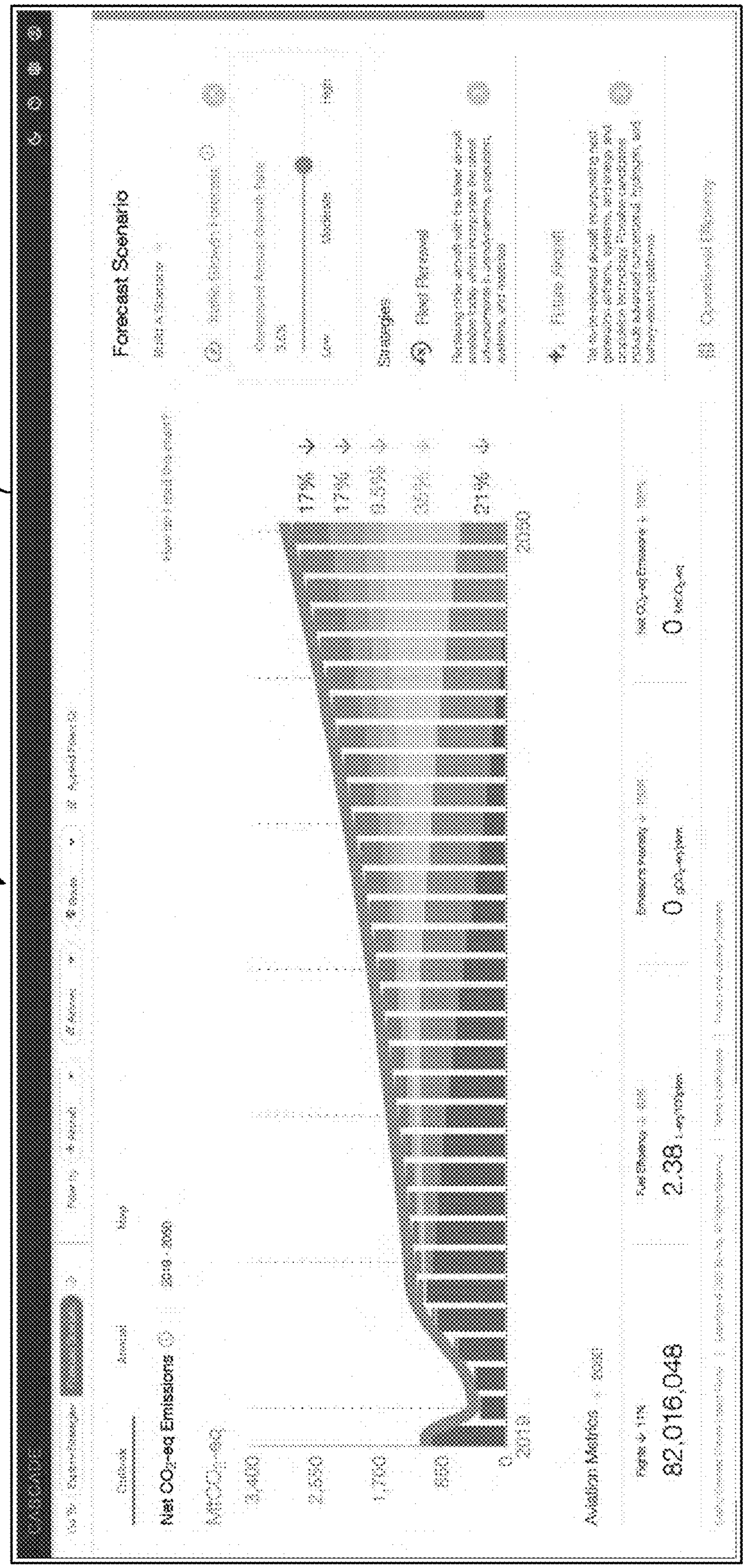


FIG. 36A

300

10

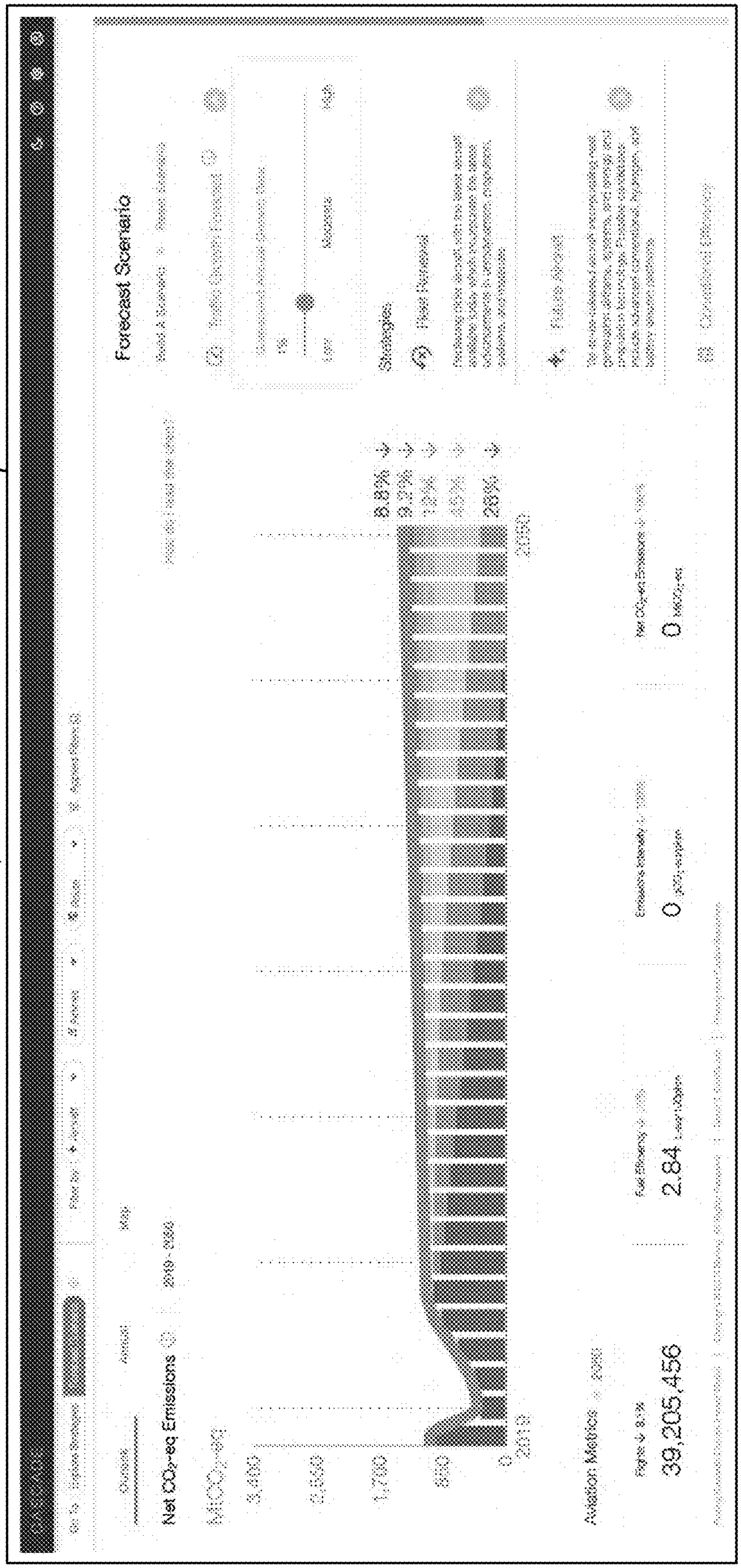


FIG. 36B

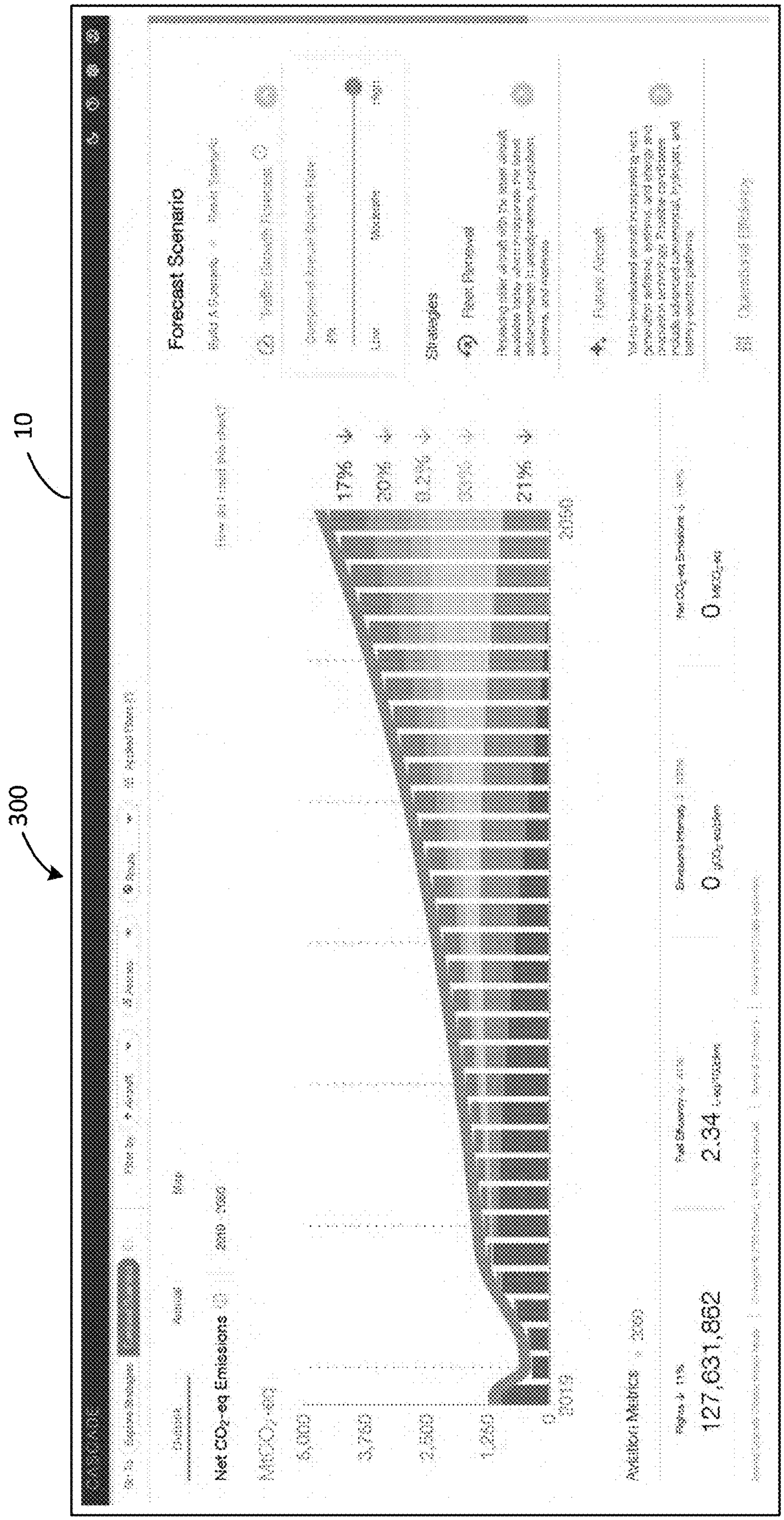

300
10
Net CO2-eq Emissions
Forecast Scenario
Strategies
5,000
3,750
2,500
1,250
0
2019
2050
17%
20%
21%
127,631,862
2.34
0
0

FIG. 36C

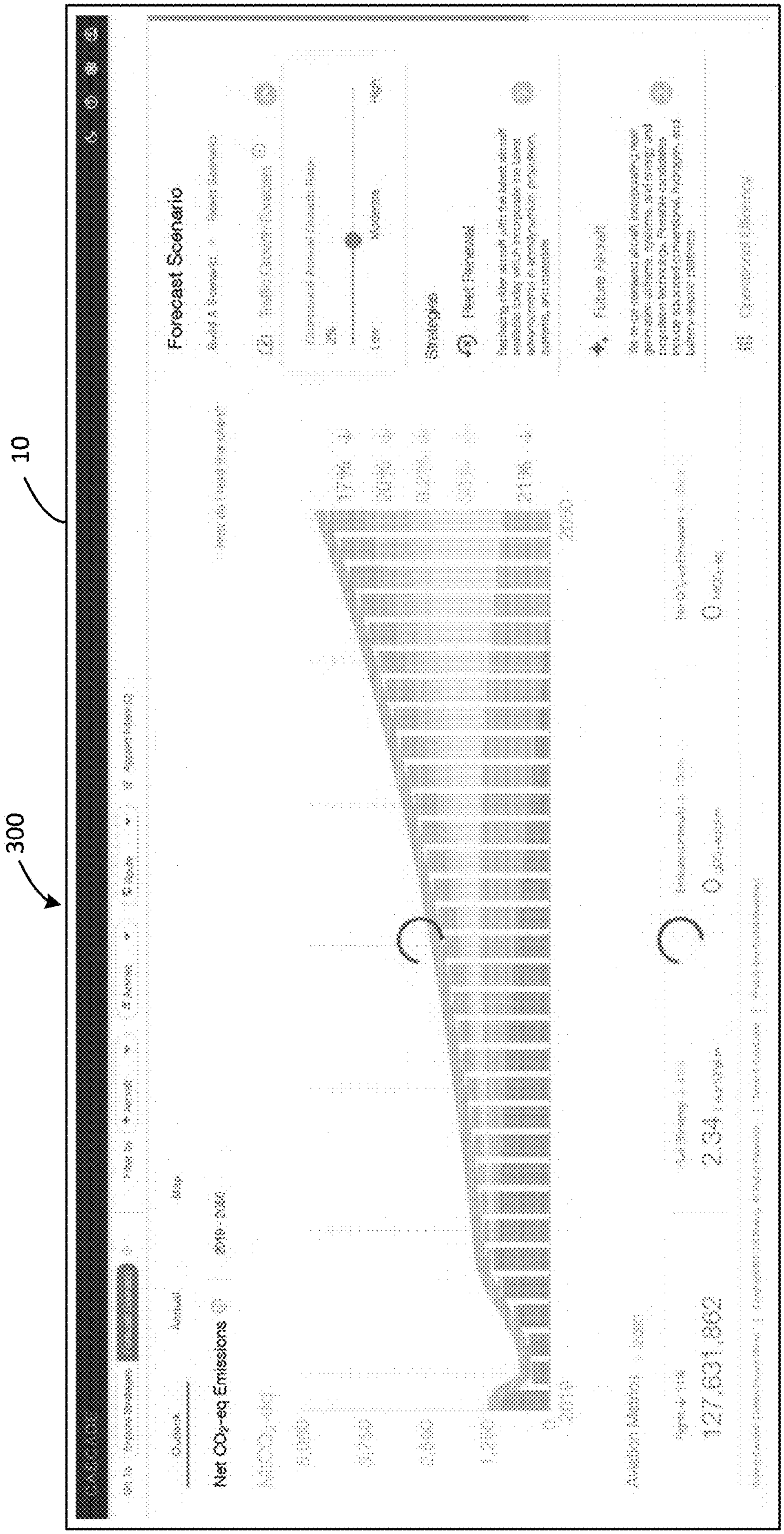

300
10
Forecast Scenario
Net CO2-eq Emissions
127,631,862
2.34
2019
2050

FIG. 36D

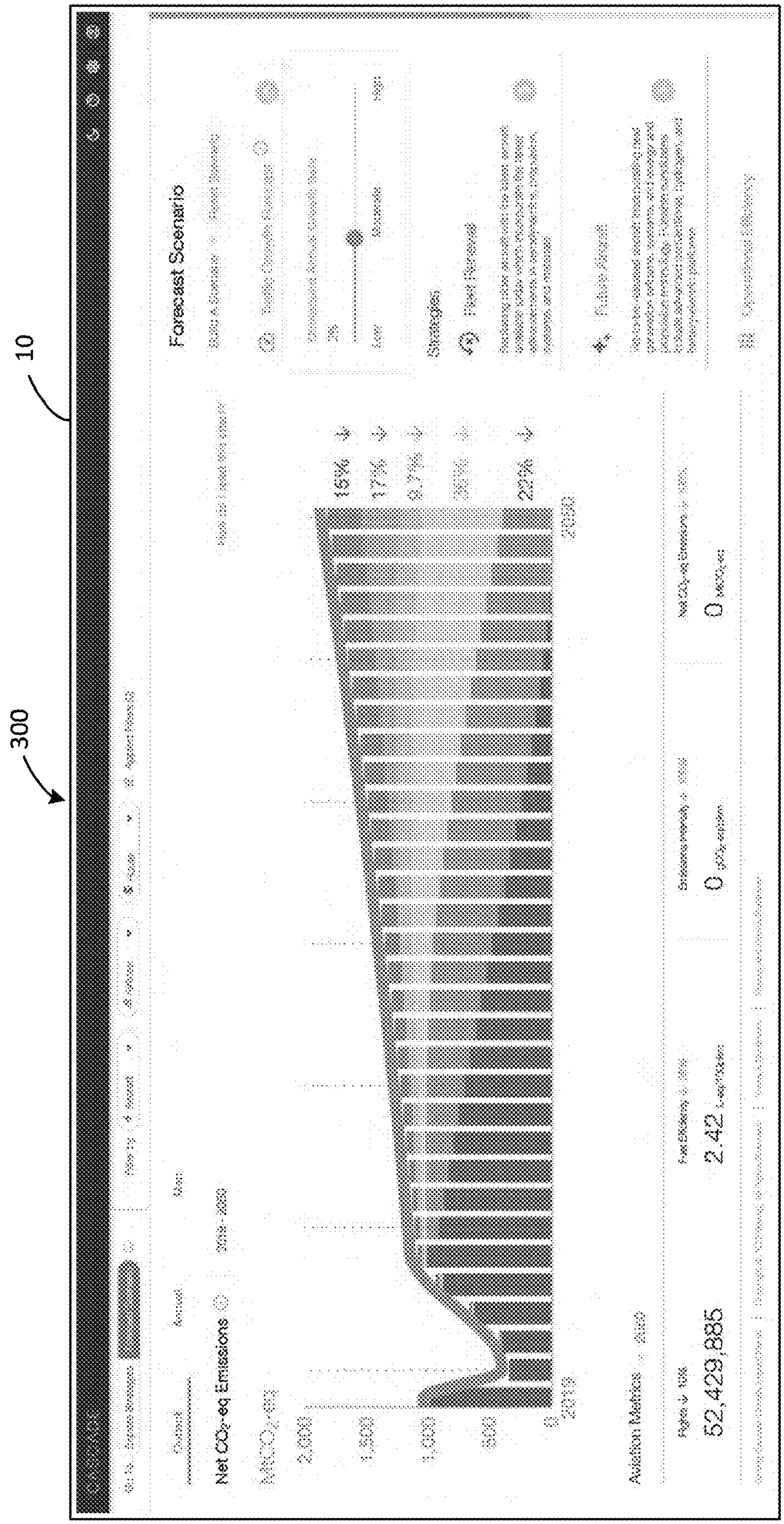

300
10
Forecast Scenario
Strategies
Fleet Renewal
Net CO_2-eq Emissions
2,000
1,500
1,000
500
0
2019
2050
16%
17%
22%
Aviation Metrics
52,429,885
2.42
0
0

FIG. 36E

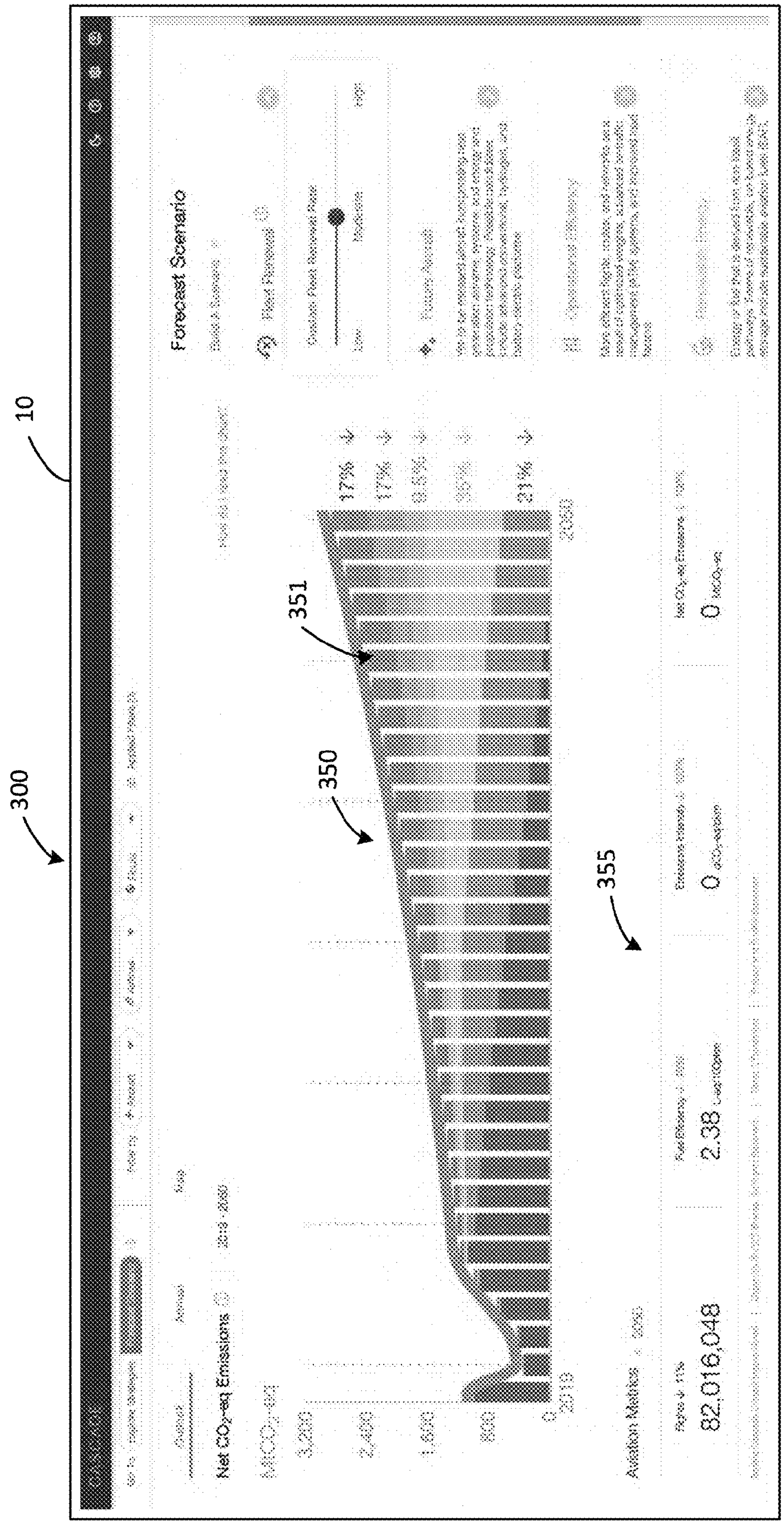

10
300
350
351
355
Forecast Scenario
Net CO2-eq Emissions
Aviation Metrics
82,016,048
2.38
0
0
2019
2050
17%
17%
21%

FIG. 37

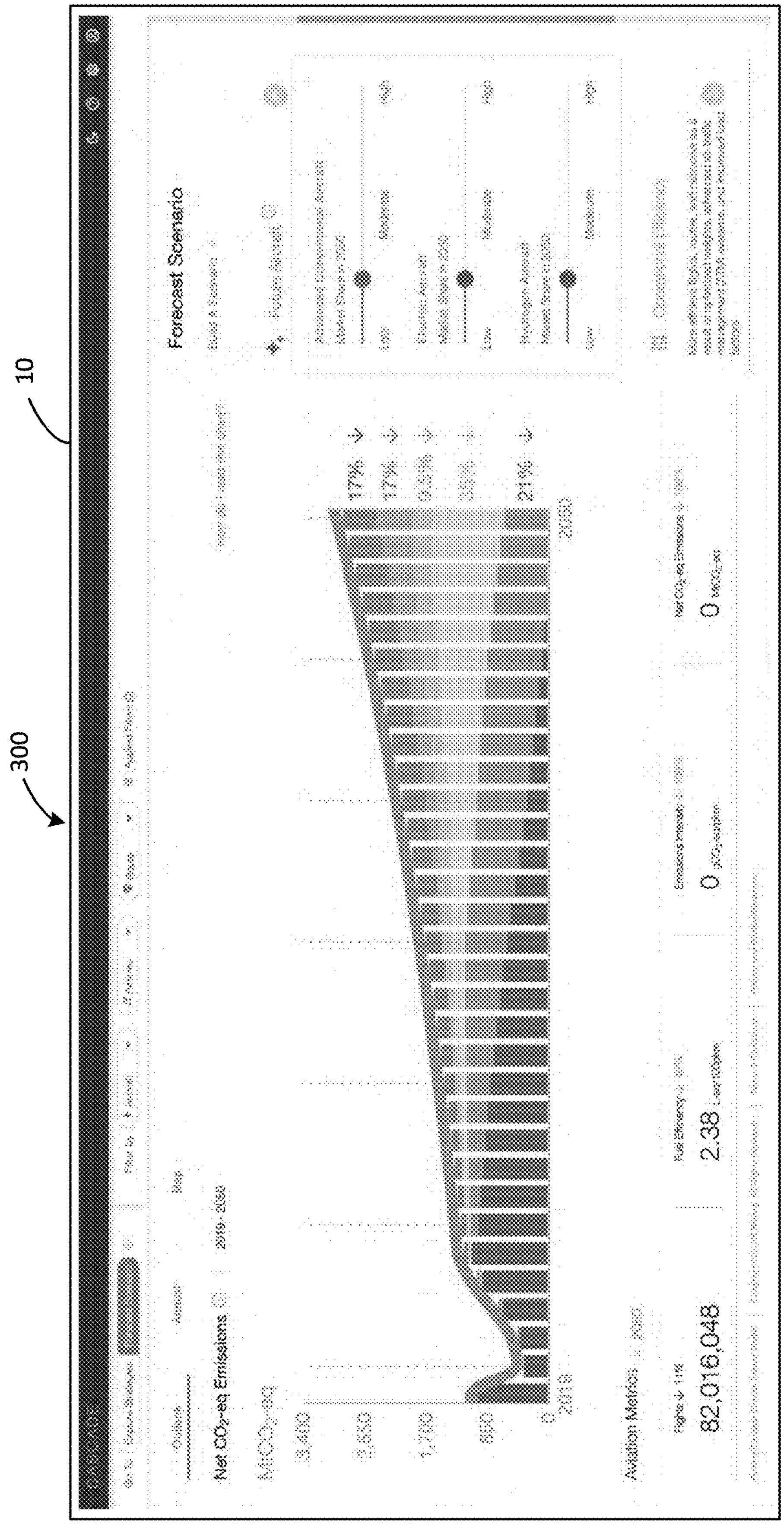

300
10
Forecast Scenario
Net CO2-eq Emissions
2019 - 2050
3,400
2,550
1,700
850
0
2019
2050
Aviation Metrics
82,016,048
2.38
0
0

FIG. 38A

300

10

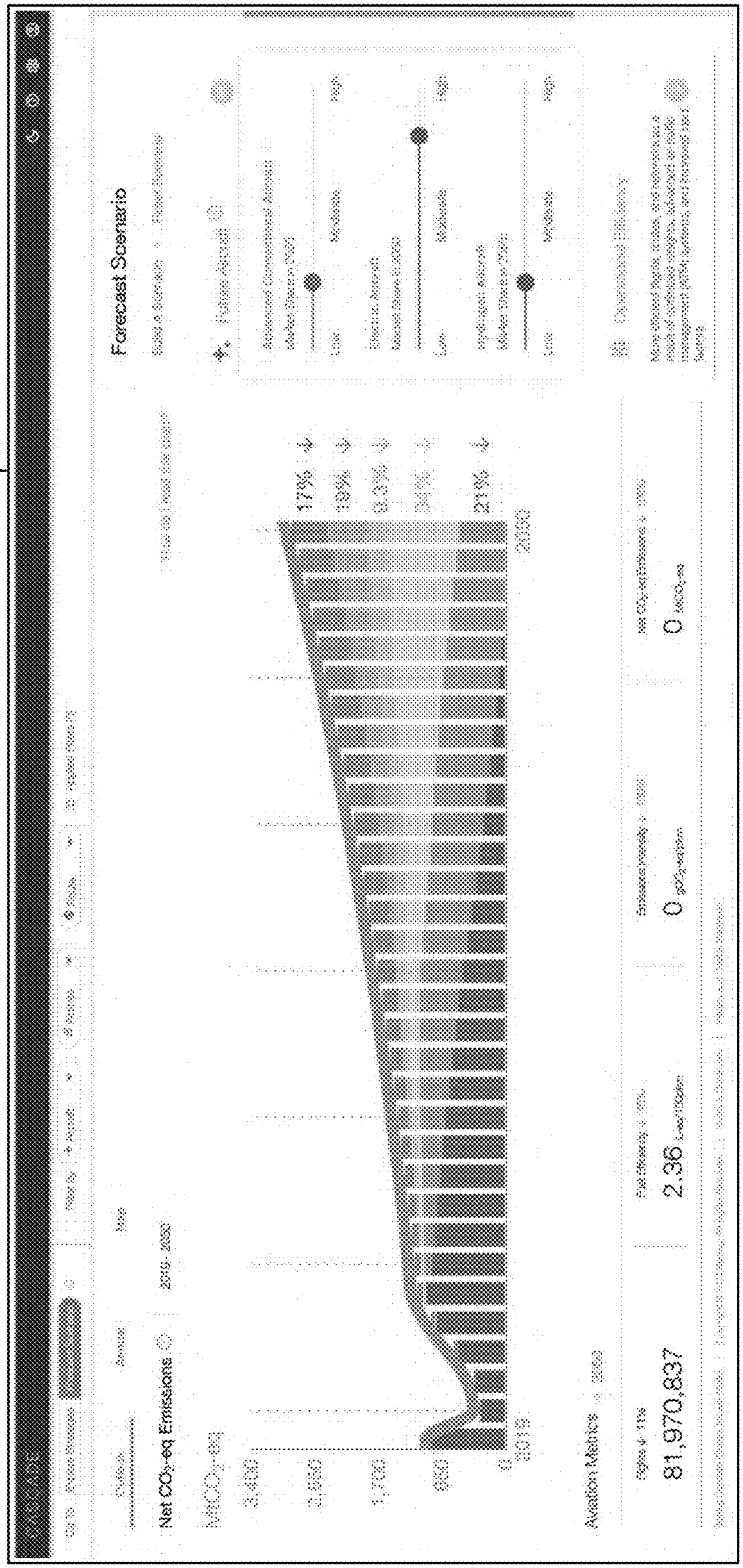


FIG. 38B

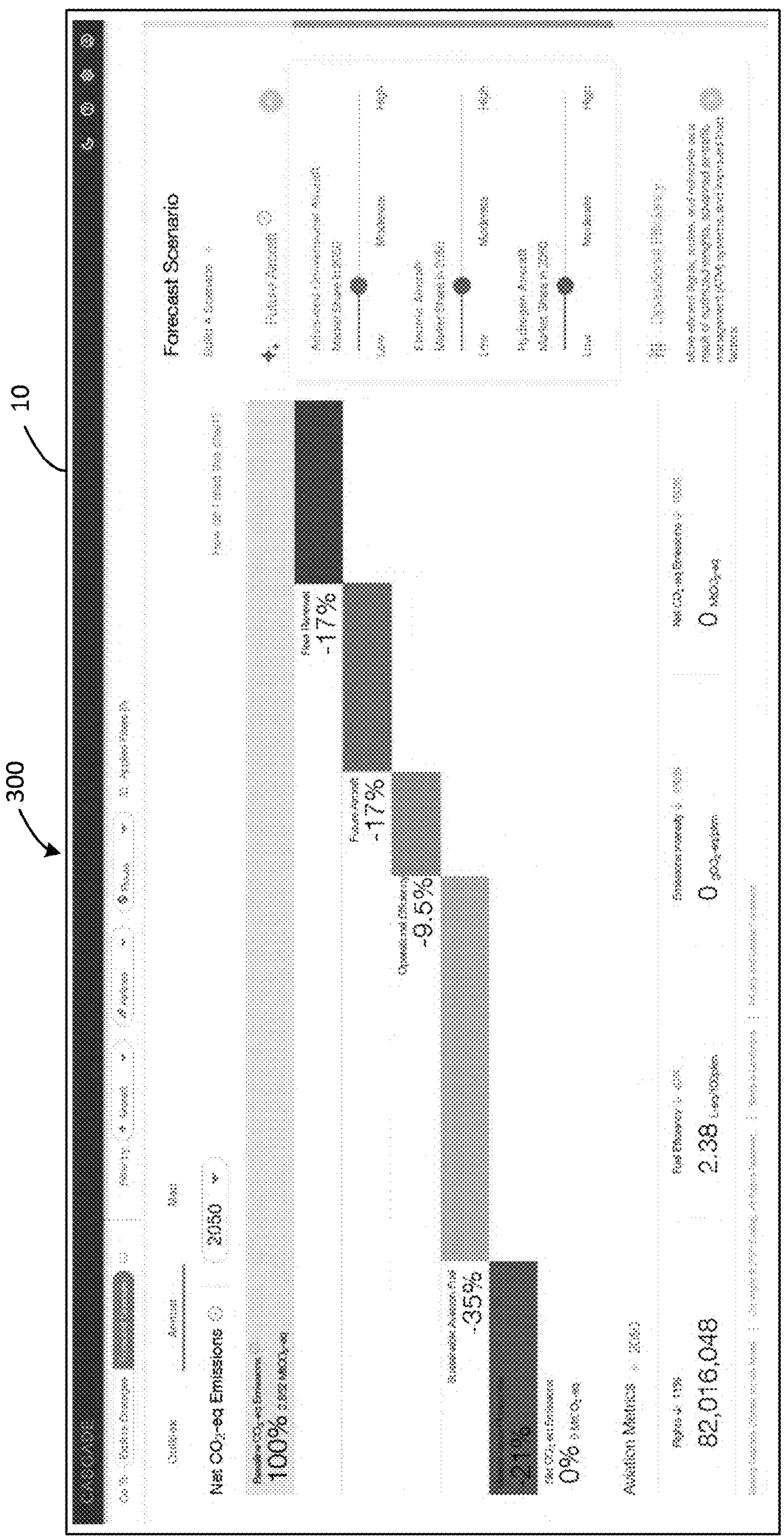

300
10
Net CO2-eq Emissions
100%
2050
-17%
-17%
-9.5%
-35%
0%
Forecast Scenario
Aviation Metrics
82,016,048
2.38
0
0

FIG. 39A

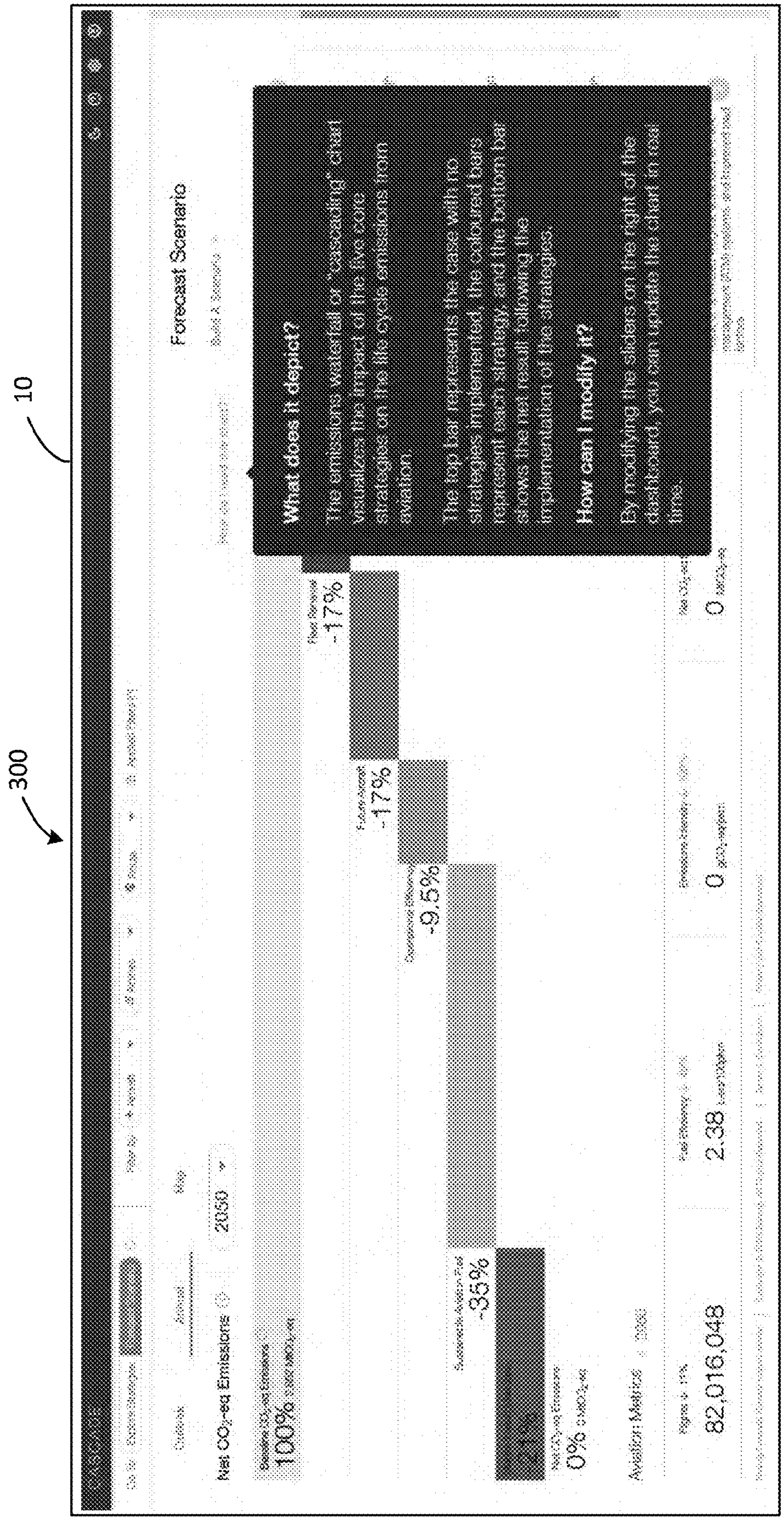

300
10
CASCADE
Net CO₂-eq Emissions
2050
Forecast Scenario
100%
-17%
-17%
-9.5%
-35%
0%
What does it depict?
The emissions waterfall or "cascading" chart visualizes the impact of the five core strategies on the life cycle emissions from aviation.
The top bar represents the case with no strategies implemented, the coloured bars represent each strategy, and the bottom bar shows the net result following the implementation of the strategies.
How can I modify it?
By modifying the sliders on the right of the dashboard, you can update the chart in real time.
Aviation Metrics
82,016,048
2.38
0
0

FIG. 39B

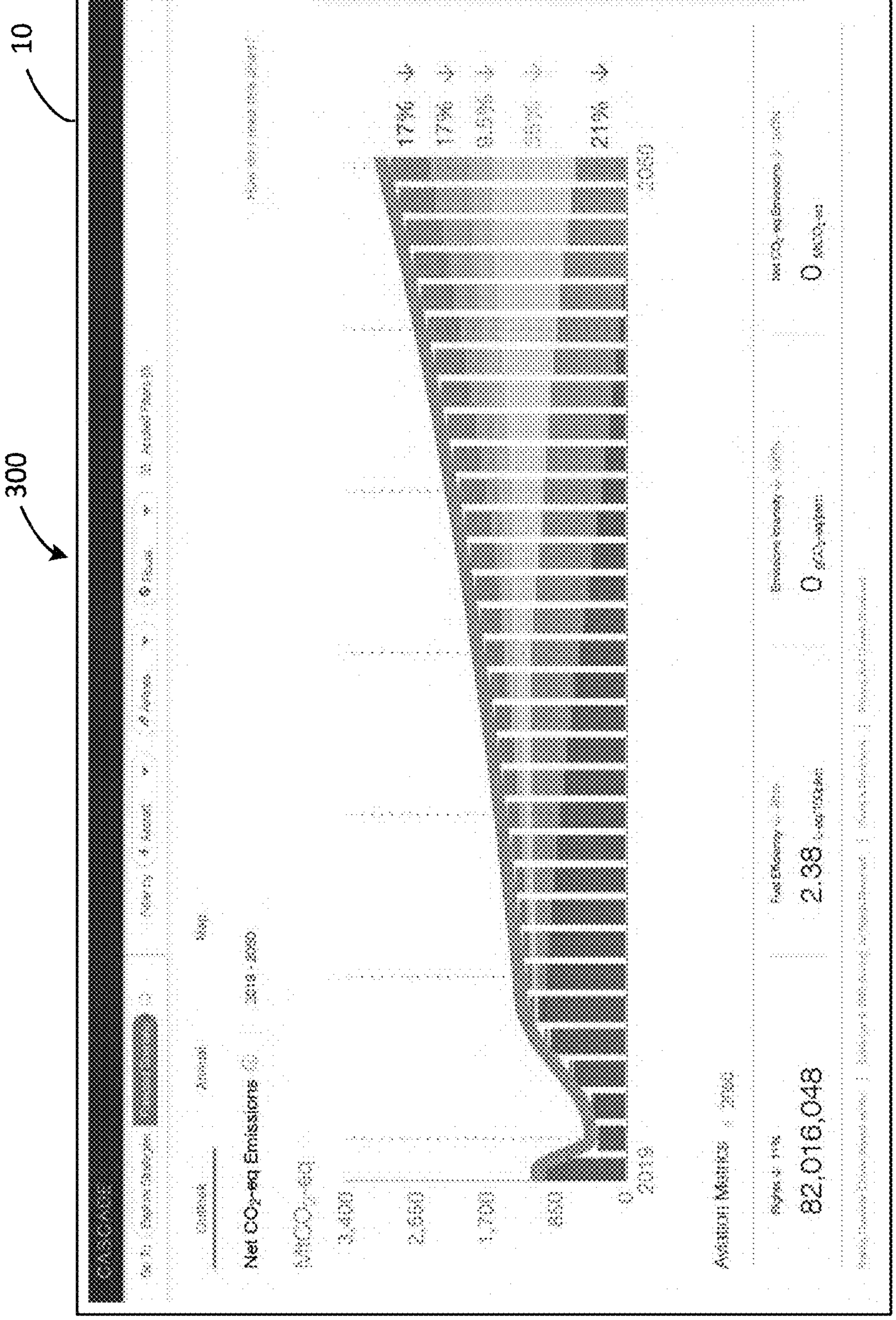

300
10
Net CO_2-eq Emissions
Forecast Scenario
3,400
2,550
1,700
850
0
2019
2050
17%
21%
82,016,048
2.38
0
0

FIG. 40A

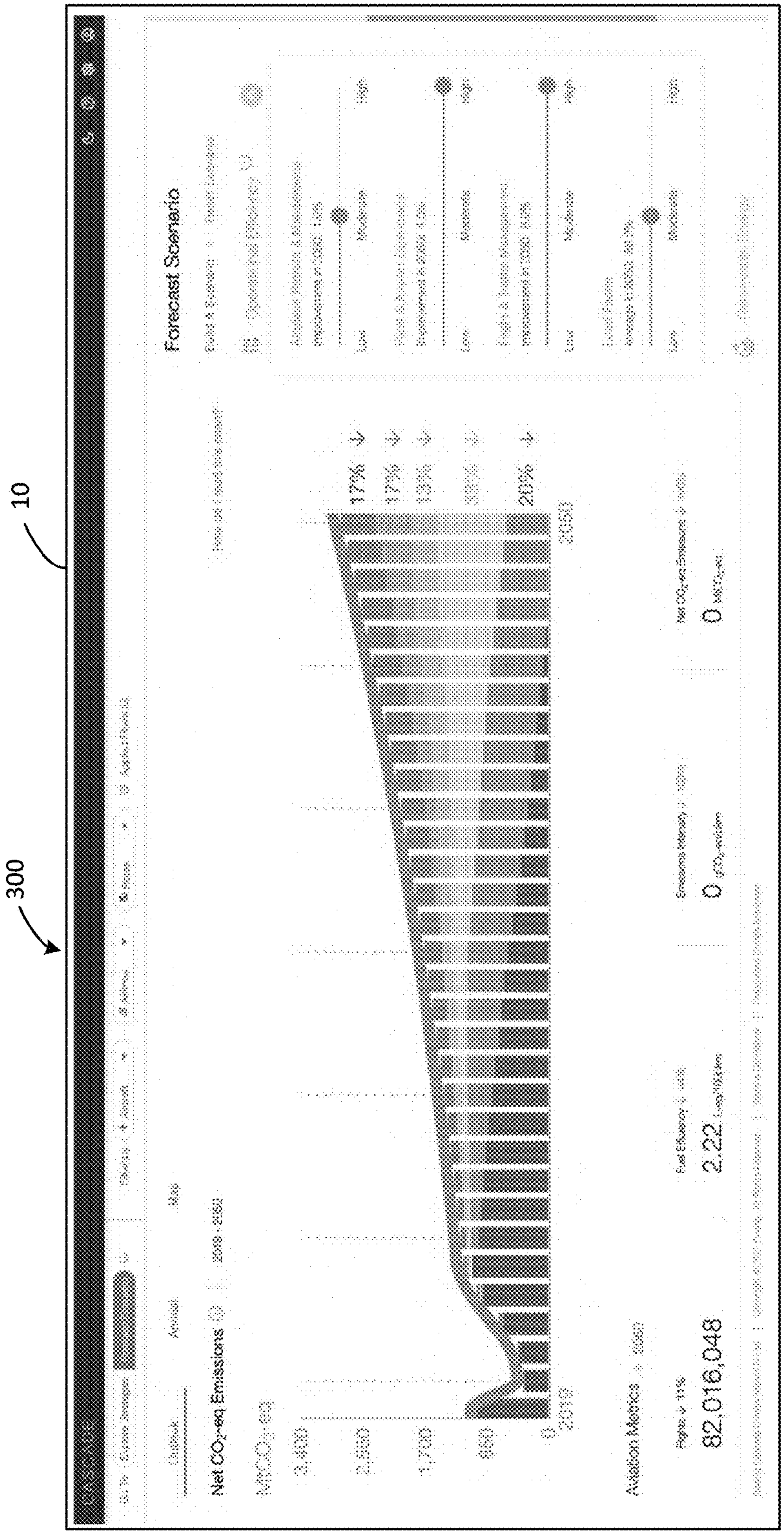

300
10
Net CO_2-eq Emissions
3,400
2,550
1,700
850
0
2019
2050
17%
17%
18%
28%
20%
Forecast Scenario
Aviation Metrics
82,016,048
2.22
0
0

FIG. 40B

300

10

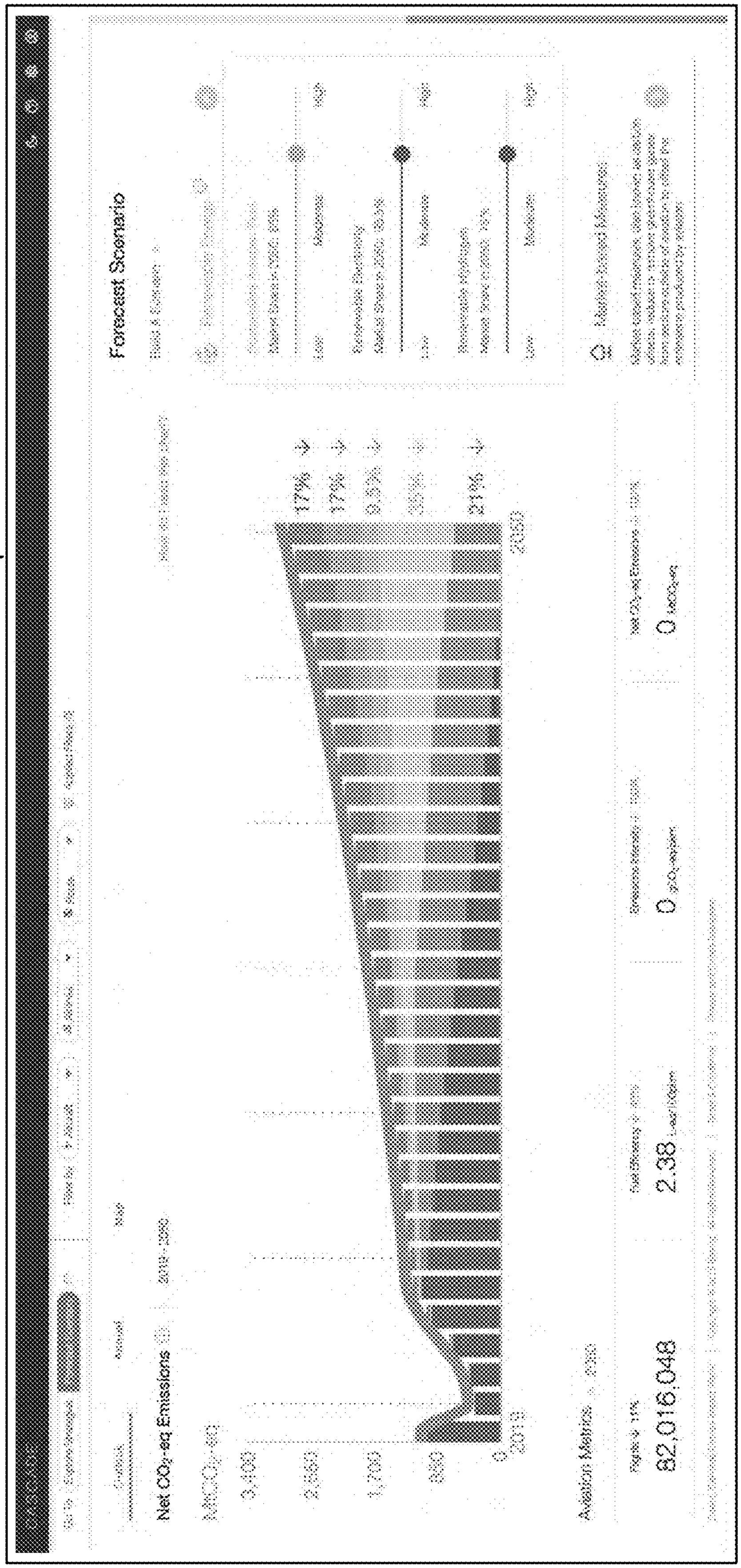


FIG. 41A

300

10

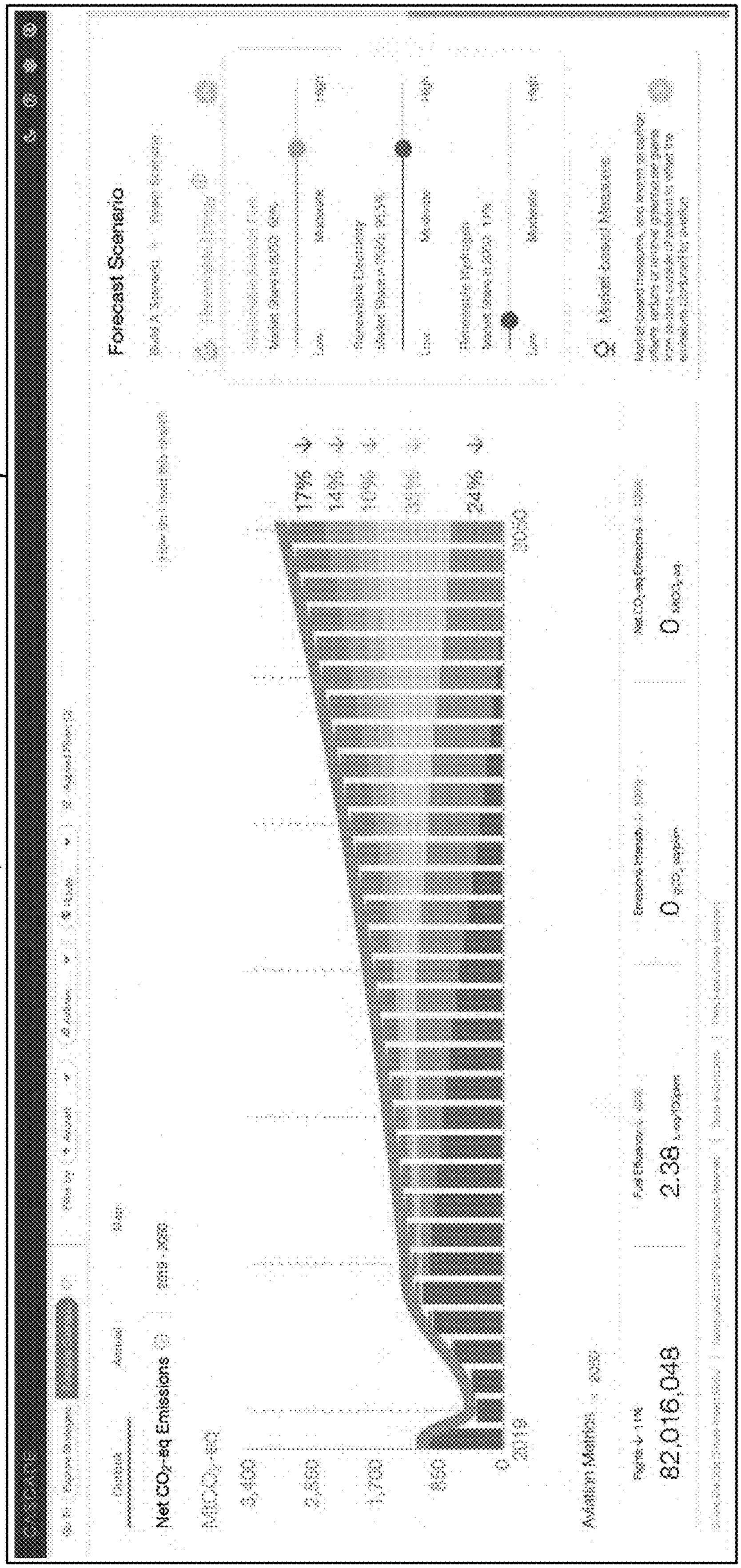


FIG. 41B

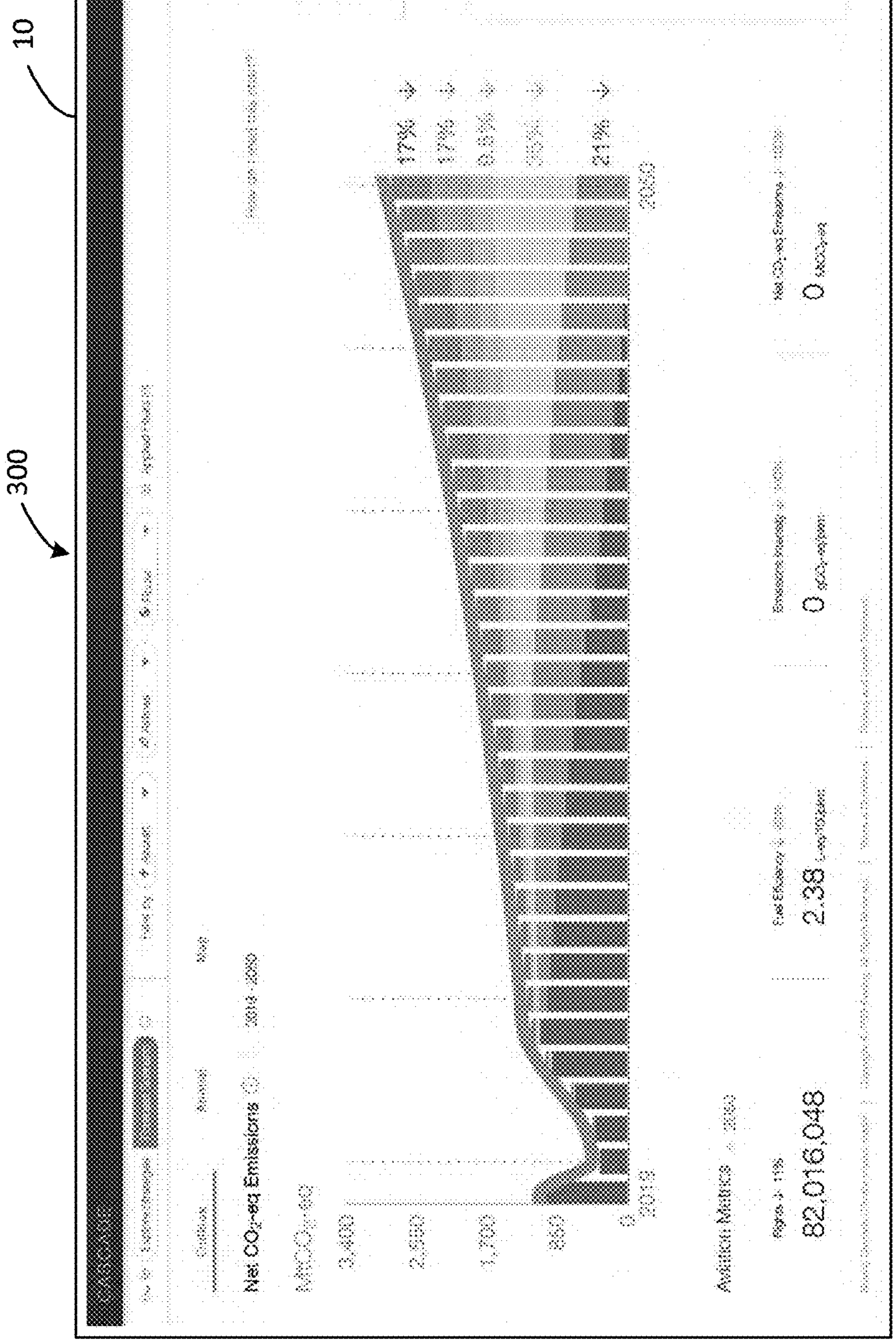

300
10
Net CO2-eq Emissions
Forecast Scenario
3,400
2,550
1,700
850
0
2019
2050
Additional Metrics
82,016,048
2.38
0
0

FIG. 42A

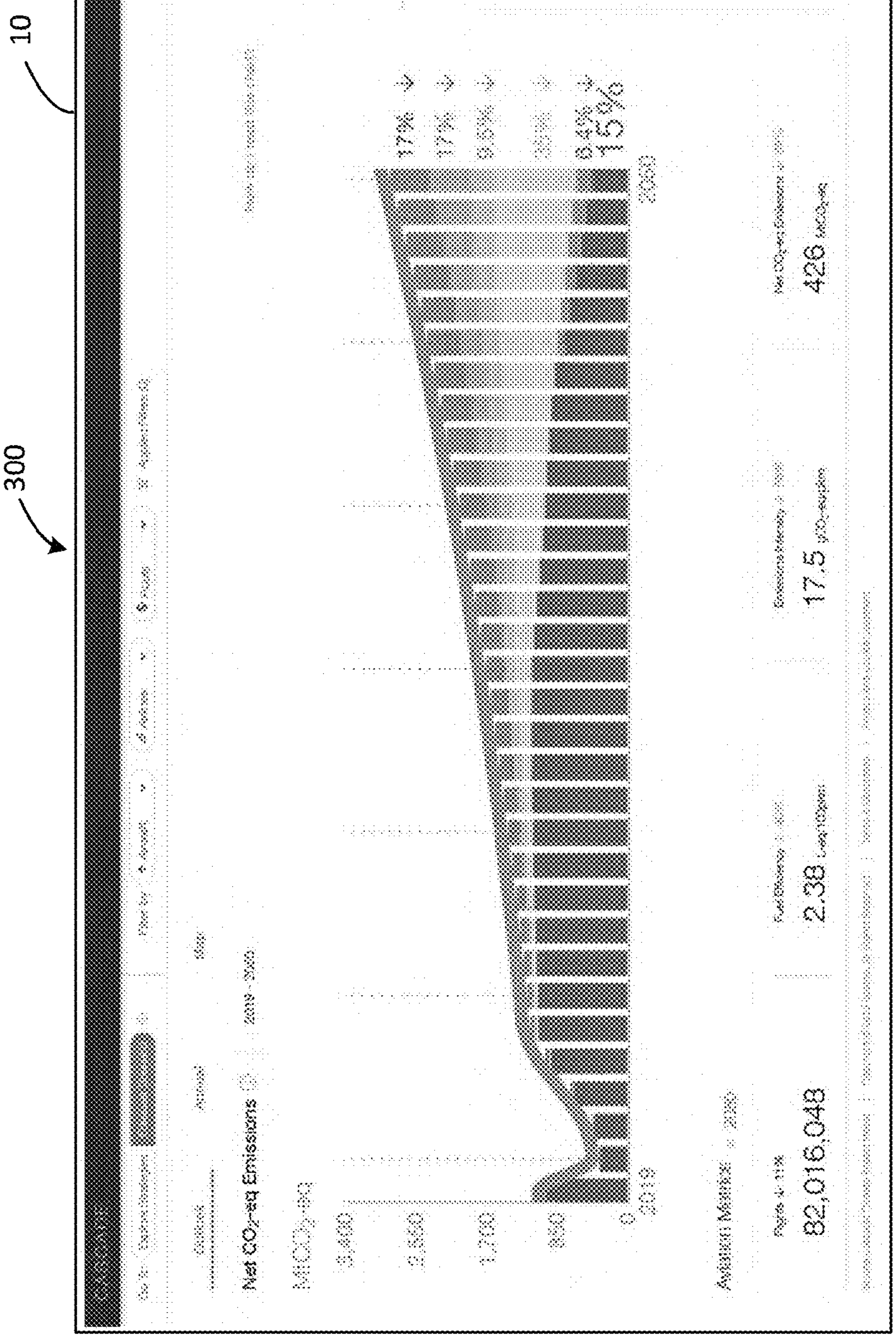

10
300
Net CO_2-eq Emissions
3,400
2,550
1,700
850
0
2019
2050
17%
17%
9.5%
6.4%
15%
Forecast Scenario
Aviation Metrics
82,016,048
2.38
17.5
426

FIG. 42B

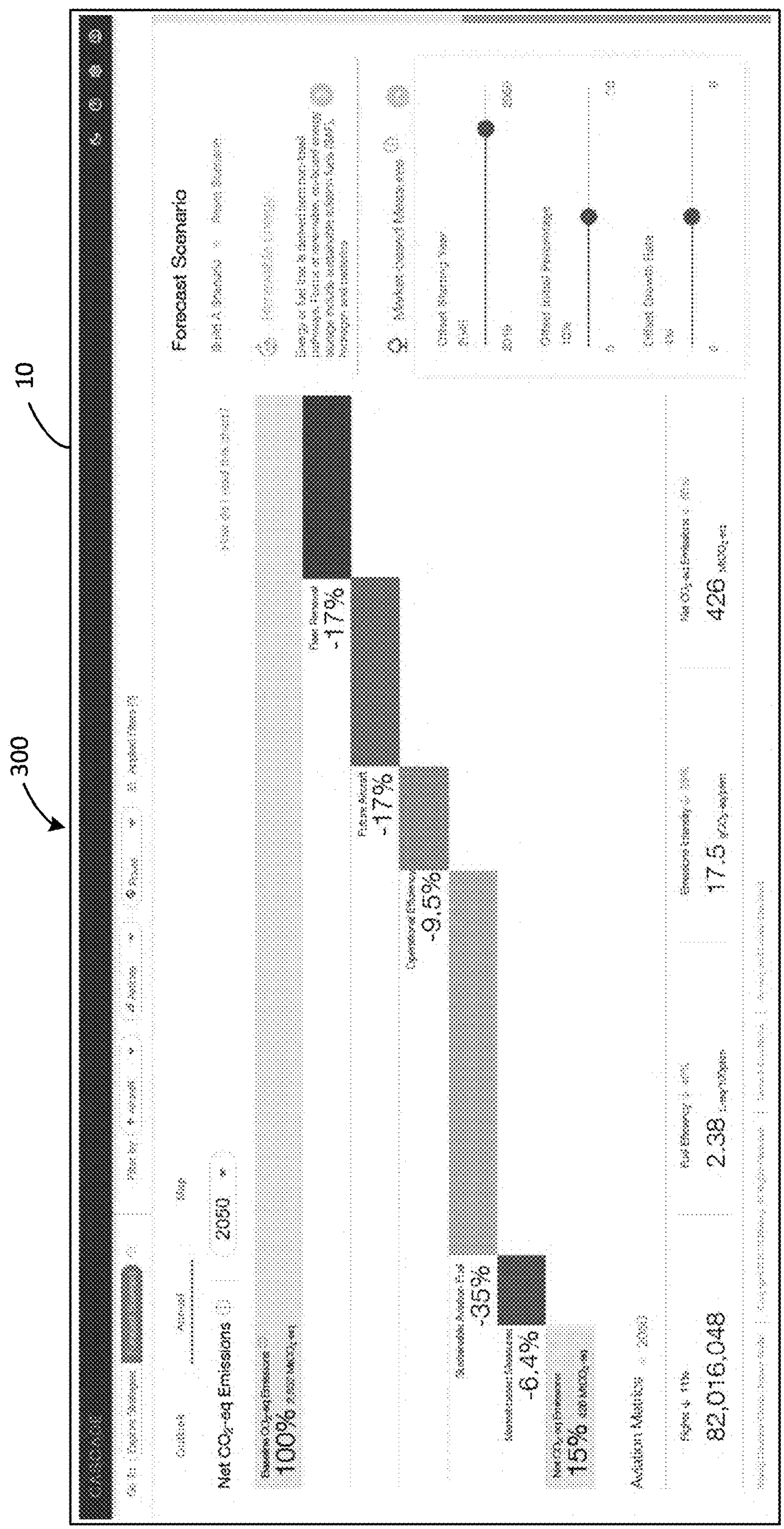

10
300
Forecast Scenario
Net CO2-eq Emissions
2050
100%
-17%
-17%
-9.5%
-35%
-6.4%
15%
Aviation Metrics
82,016,048
2.38
17.5
426

FIG. 43


300
10
Forecast Scenario
Net CO2-eq Emissions
2050
100%
-17%
-17%
-9.5%
35%
-6.4%
15%
Aviation Metrics
82,016,048
2.38
17.5
426

FIG. 44A

300

10

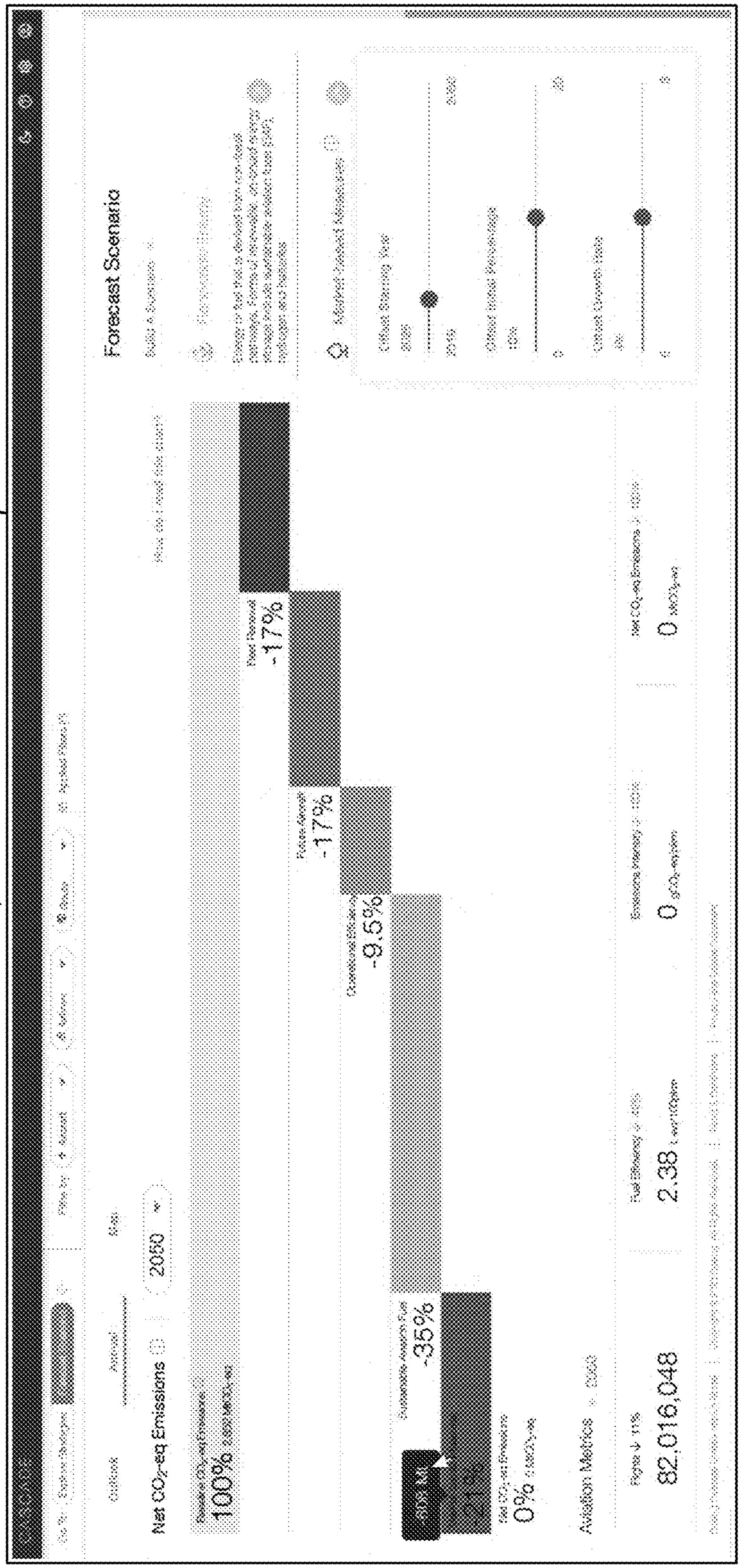


FIG. 44B

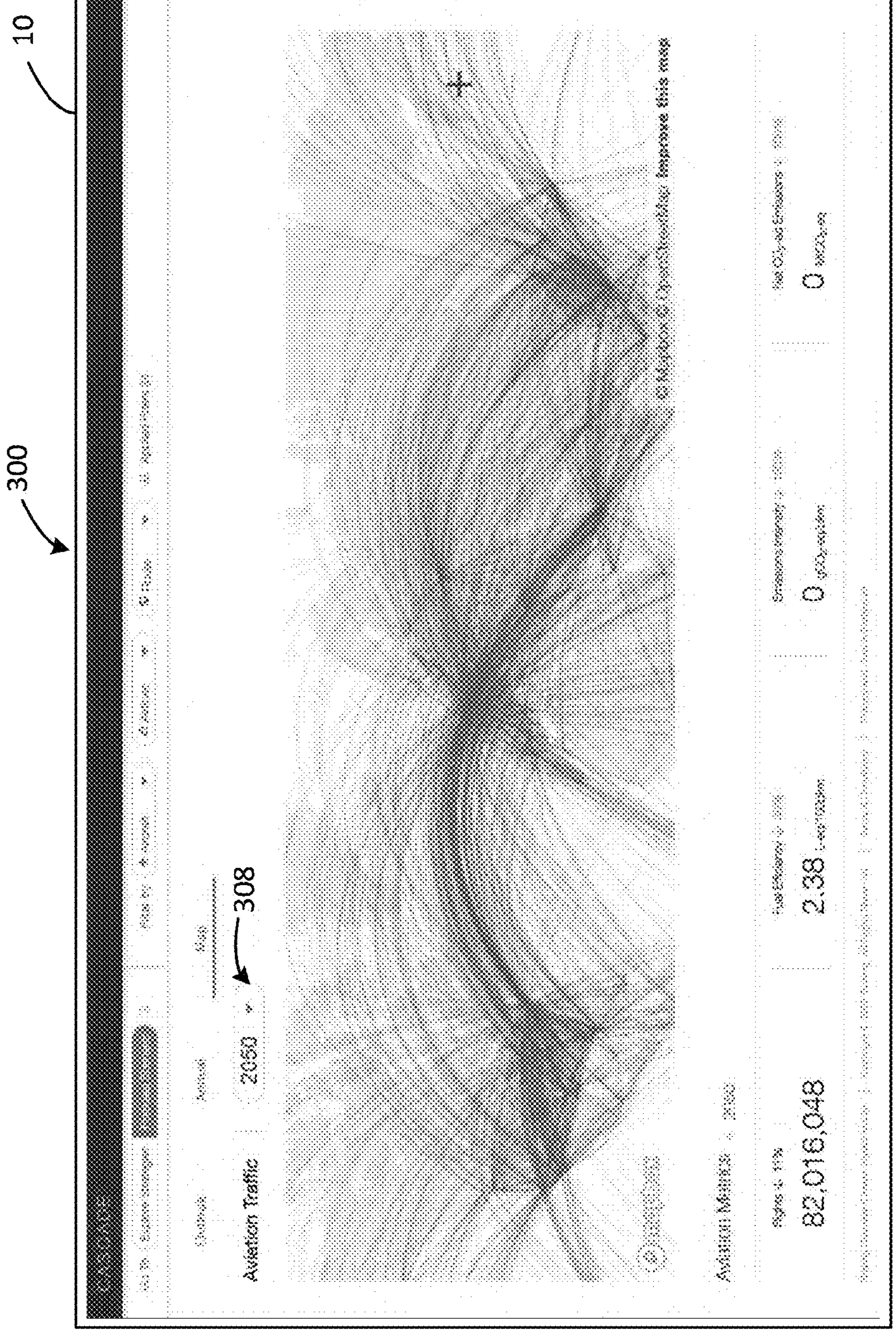

300
10
308
Aviation Traffic
2050
Map
Forecast Scenario
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
© Mapbox © OpenStreetMap Improve this map
Aviation Metrics
82,016,048
2.38
0
0

FIG. 45

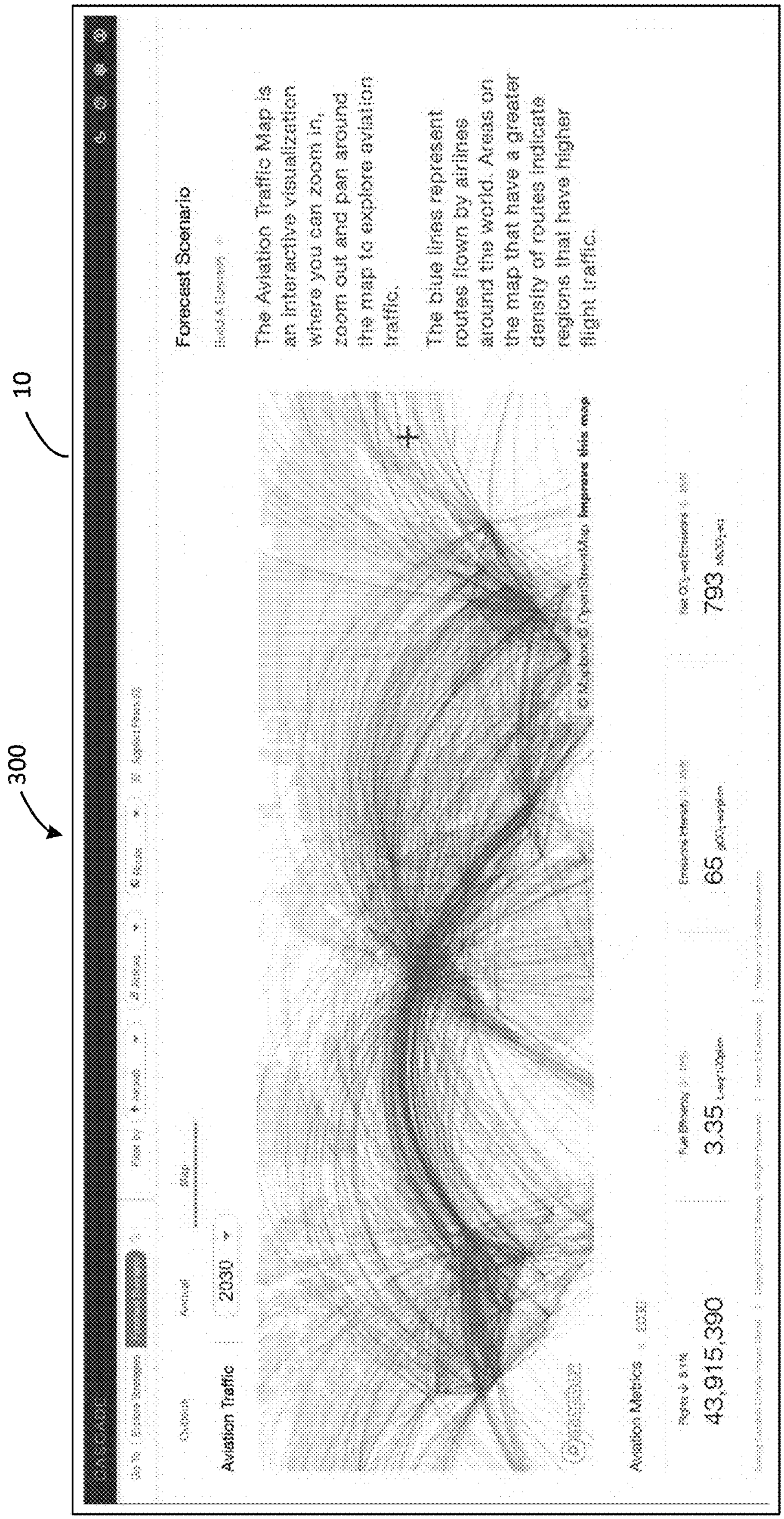

300
10
Aviation Traffic
2030
Forecast Scenario
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
Aviation Metrics
43,915,390
3.35
65
793

FIG. 46A

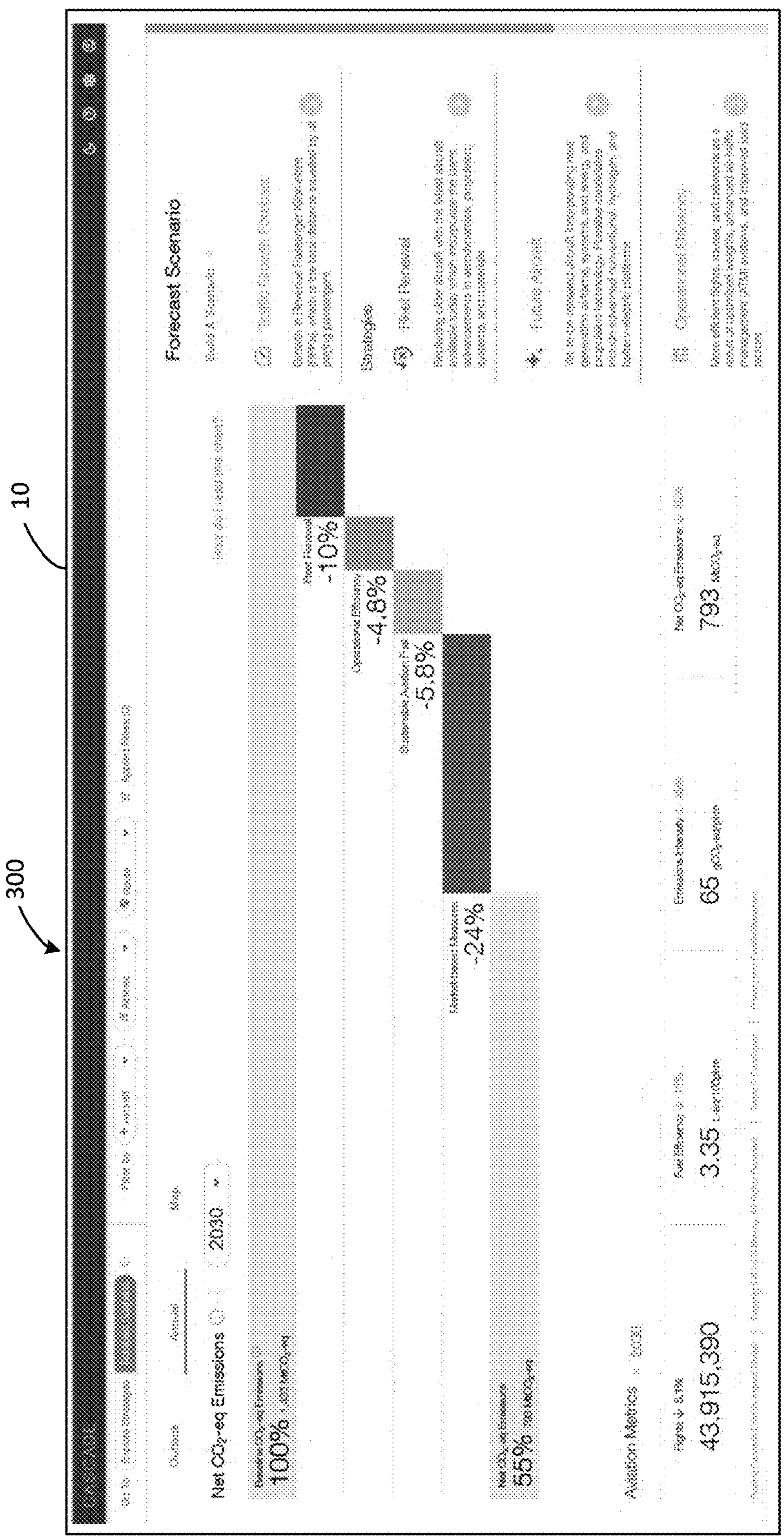

300
10
Net CO2-eq Emissions
2030
100%
-10%
-4.8%
-5.8%
-24%
55%
Forecast Scenario
Strategies
Aviation Metrics
43,915,390
3.35
65
793

FIG. 46B

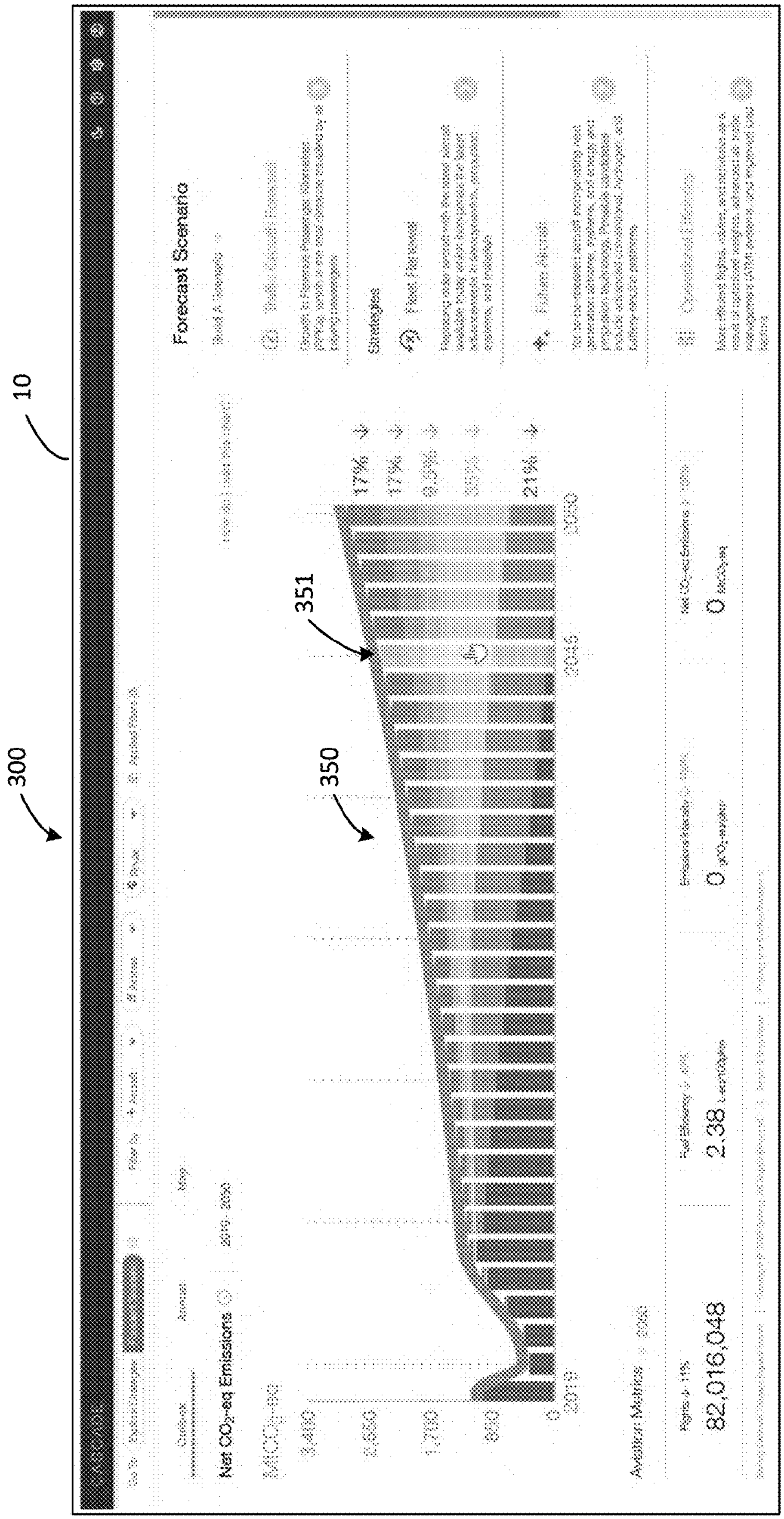

10
300
350
351
Net CO2-eq Emissions
Forecast Scenario
Strategies
Aviation Metrics
2019
2045
2050
17%
17%
21%
82,016,048
2.38
0
0

FIG. 47A

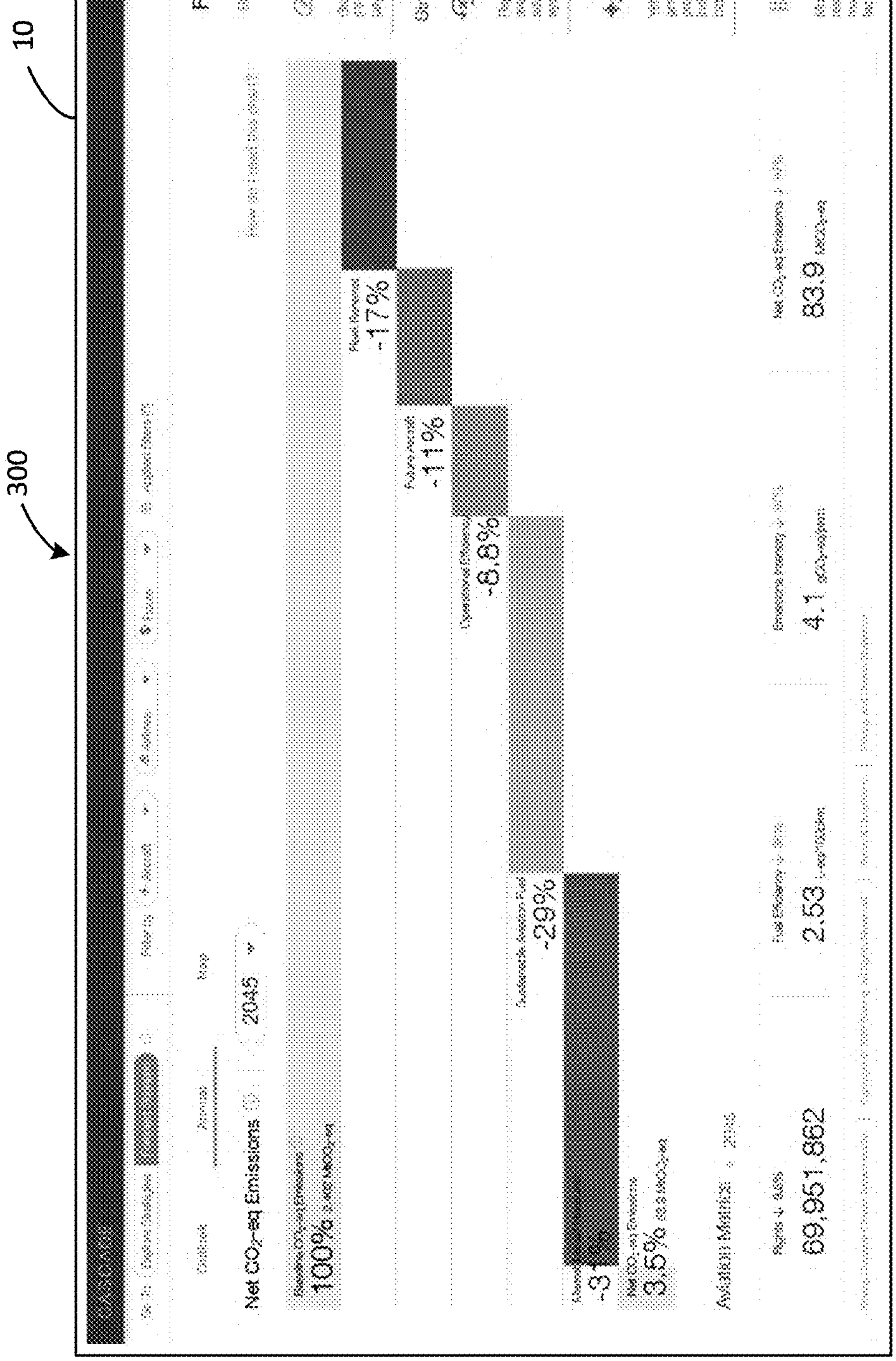

300
10
Forecast Scenario
Strategies
Net CO2-eq Emissions
2045
100%
-17%
-11%
-8.8%
-29%
3.5%
Aviation Metrics
69,951,862
2.53
4.1
83.9

FIG. 47B

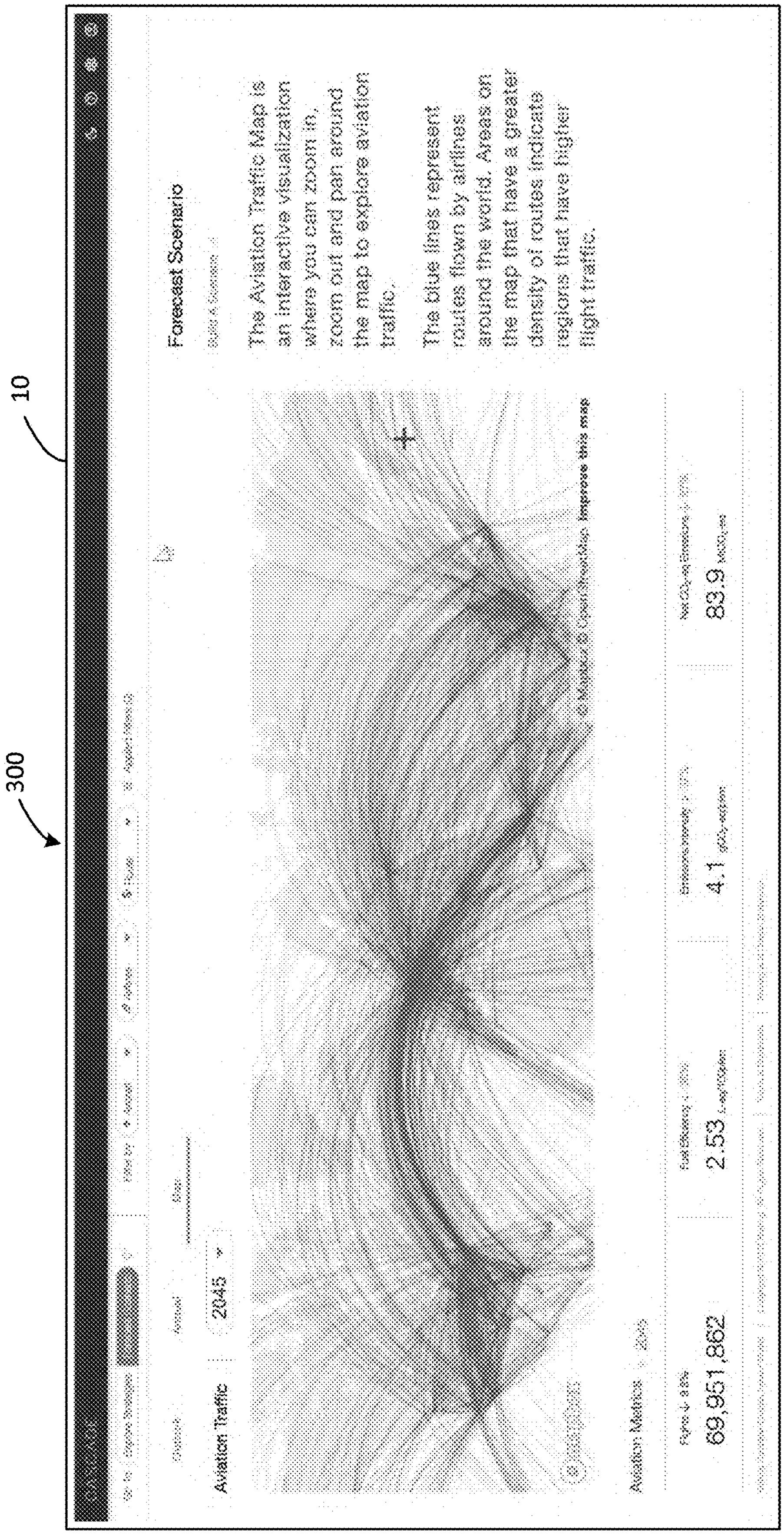

300
10
Aviation Traffic
2045
Forecast Scenario
The Aviation Traffic Map is an interactive visualization where you can zoom in, zoom out and pan around the map to explore aviation traffic.
The blue lines represent routes flown by airlines around the world. Areas on the map that have a greater density of routes indicate regions that have higher flight traffic.
Improve this map
Aviation Metrics
69,951,862
2.53
4.1
83.9

FIG. 47C

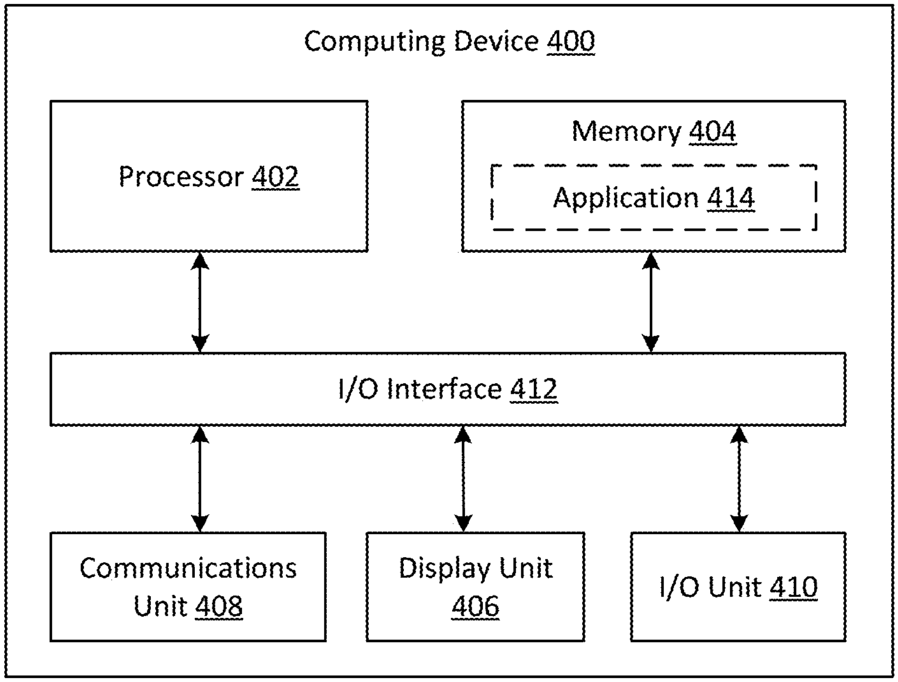

Computing Device 400
Processor 402
Memory 404
Application 414
I/O Interface 412
Communications Unit 408
Display Unit 406
I/O Unit 410

FIG. 48

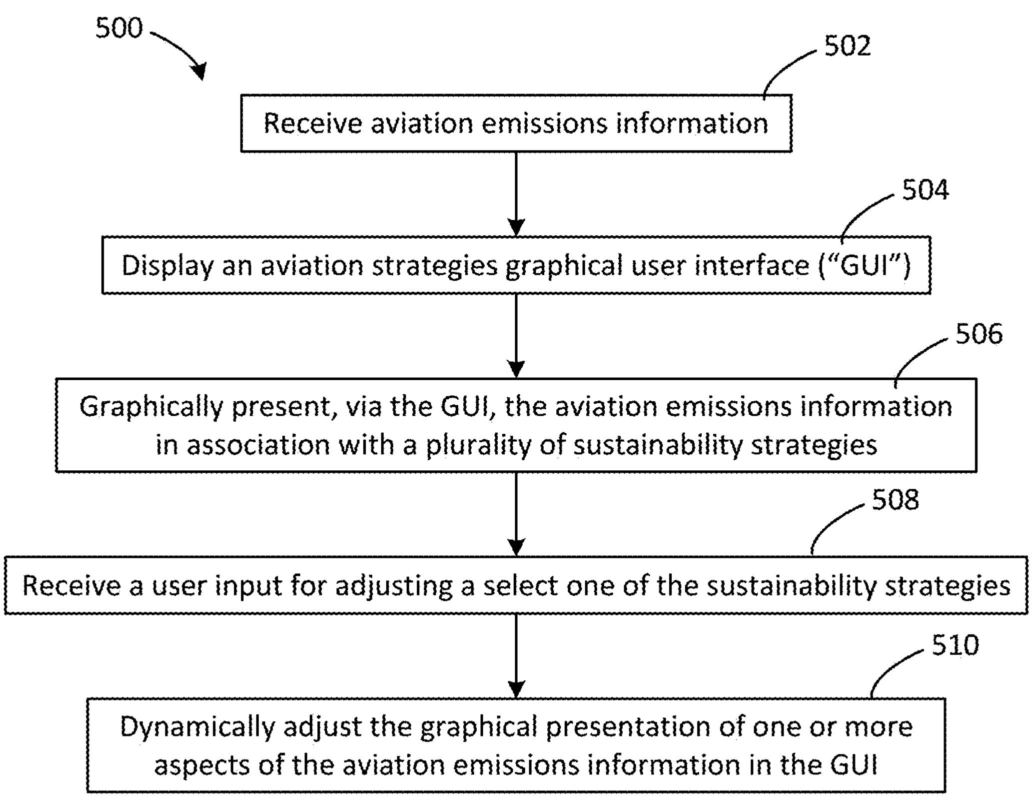

500
502
Receive aviation emissions information
504
Display an aviation strategies graphical user interface ("GUI")
506
Graphically present, via the GUI, the aviation emissions information in association with a plurality of sustainability strategies
508
Receive a user input for adjusting a select one of the sustainability strategies
510
Dynamically adjust the graphical presentation of one or more aspects of the aviation emissions information in the GUI

FIG. 49

SYSTEM AND METHOD FOR DYNAMIC DISPLAY OF AIRCRAFT EMISSIONS DATA

TECHNICAL FIELD

The present disclosure generally relates to presentment of emissions data for one or more aircraft.

BACKGROUND

The aviation industry has pledged to maintain 2019 levels of carbon emissions out to 2050 and to also reach net-zero carbon emissions by the end of that timeframe. There are many different ways to apply sustainability measures or strategies. However, existing techniques for displaying emissions data for the aviation industry include static views, graphs, and/or charts of discrete aspects of the available data, thus making it difficult and time-consuming to model and/or analyze such data and determine which of the strategies to implement.

SUMMARY

The invention is intended to solve the above-noted problems by providing systems and methods that are designed, among other things, to dynamically model and depict overall emissions of the aviation industry and changes thereto when taking into account traffic growth and introduction of sustainability strategies, such as new and/or improved technologies, an increase in operational efficiency, and carbon offsets. Using the dynamic tool described herein, users can define scenarios on how to reduce emissions through the introduction of different sustainability strategies, both statically and over time, and analyze the impact of those strategies on emissions.

For example, one embodiment provides a computer-implemented method of graphically displaying sustainability strategies for an aviation industry, the method comprising: receiving, at one or more processors, aviation emissions information for a plurality of flights and a select time period: displaying, on a display device, an aviation strategies graphical user interface: graphically presenting, via the aviation strategies graphical user interface and using the one or more processors, the aviation emissions information in association with a plurality of sustainability strategies: receiving, via one or more input devices of the aviation strategies graphical user interface, a user input for adjusting a select strategy of the plurality of sustainability strategies; and based on the user input, dynamically adjusting, using the one or more processors, the graphical presentation of one or more aspects of the aviation emissions information in the aviation strategies graphical user interface.

Another exemplary embodiment provides a system comprising: a display device; and one or more processors communicatively coupled to the display device, the one or more processors configured to: receive aviation emissions information for a plurality of flights and a select time period; and display, via the display device, an aviation strategies graphical user interface, wherein the aviation strategies graphical user interface is configured to: graphically present the aviation emissions information in association with a plurality of sustainability strategies: receive, via one or more input devices of the aviation strategies graphical user interface, a user input for adjusting a select strategy of the plurality of sustainability strategies; and based on the user input, dynamically adjust the graphical presentation of one or more aspects of the aviation emissions information.

Another exemplary embodiment provides a non-transitory computer-readable storage medium comprising instructions that, when executed by one or more processors, cause the one or more processors to: receive aviation emissions information for a plurality of flights and a select time period: display, via the display device, an aviation strategies graphical user interface; graphically present, via the aviation strategies graphical user interface, the aviation emissions information in association with a plurality of sustainability strategies: receive, via one or more input devices of the aviation strategies graphical user interface, a user input for adjusting a select strategy of the plurality of sustainability strategies; and based on the user input, dynamically adjust the graphical presentation of one or more aspects of the aviation emissions information in the aviation strategies graphical user interface.

These and other embodiments, and various permutations and aspects, will become apparent and be more fully understood from the following detailed description and accompanying drawings, which set forth illustrative embodiments that are indicative of the various ways in which the principles of the invention may be employed.

BRIEF DESCRIPTION OF THE DRAWINGS

The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

FIG. **1** is a screenshot of an exemplary graphical user interface for depicting an exemplary map view of a dynamic aviation emissions modeling tool, the map view including all flight paths in a given year and corresponding emissions data, in accordance with certain embodiments.

FIGS. **2**A to **3**B are close-up screenshot views of a timeline variable and the emissions data portion of the map view of FIG. **1** as the timeline variable is changed from year to day, in accordance with certain embodiments.

FIG. **4** is a close-up screenshot view of a first filter menu for changing a distance parameter of the flight paths shown in the map view of FIG. **1**, in accordance with certain embodiments.

FIG. **5** is a close-up screenshot view of a second filter menu for changing an airline parameter of the flight paths shown in the map view of FIG. **1**, in accordance with certain embodiments.

FIG. **6** is a screenshot of a filtered version of the map view of FIG. **1** after applying a selection from the first filter menu of FIG. **4**, in accordance with certain embodiments.

FIG. **7** is a screenshot of an exemplary graphical user interface for depicting a chart view of the dynamic aviation emissions modeling tool, the chart view including the flight paths shown in FIG. **6** along with the corresponding emissions data, in accordance with certain embodiments.

FIG. **8** is a screenshot of an exemplary modification of the chart view of FIG. **7** showing the CO2 emissions impact of a first set of sustainability strategies, in accordance with certain embodiments.

FIG. **9**A is another exemplary modification of the chart view of FIG. **7** showing the CO2 emissions impact of a second set of sustainability strategies, in accordance with certain embodiments.

FIG. **9**B is a close-up view of a portion of a future aircraft sustainability strategy graphic selected in FIG. **9**A, in accordance with certain embodiments.

FIG. **10** is a screenshot of an exemplary graphical user interface for depicting a dynamic view of the dynamic aviation emissions modeling tool, the dynamic view including emissions data over a select period of time for the flight paths shown in FIG. **6**, in accordance with certain embodiments.

FIGS. **11**A to **11**D are close-up views of a timeline menu for changing the time period shown in a map view, in accordance with certain embodiments.

FIGS. **12**A to **12**E are close-up views of a second filter menu for changing an airline parameter of flight paths shown in a map view, in accordance with certain embodiments.

FIG. **13**A is a screenshot of another exemplary graphical user interface for depicting another dynamic view of the dynamic aviation emissions modeling tool, the dynamic view including a carbon emissions chart showing emissions data over a select period of time and for a select group of flight paths, in accordance with certain embodiments.

FIG. **13**B is a close-up view of a plurality of levers shown in the dynamic view of FIG. **13**A, in accordance with certain embodiments.

FIGS. **14**A to **14**C are additional screenshots of the exemplary dynamic view of FIG. **13**A depicting an exemplary flow upon selecting a year in the carbon emissions chart, in accordance with certain embodiments.

FIGS. **14**D and **14**E are close-up views of an exemplary pop-up window displayed in FIGS. **14**B and **14**C, respectively, in accordance with certain embodiments.

FIG. **15** is another screenshot of the exemplary dynamic view of FIG. **13**A depicting a change in selection for a Fleet Renewal lever, in accordance with certain embodiments.

FIG. **16**A is another screenshot of the exemplary dynamic view of FIG. **15** depicting an expanded state of a Traffic Growth Forecast lever, in accordance with certain embodiments.

FIGS. **16**B and **16**C are close-up views of the expanded Traffic Growth Forecast lever shown in FIG. **16**A depicting different selections for a scenario setting of the lever, in accordance with certain embodiments.

FIG. **17**A is another screenshot of the exemplary dynamic view of FIG. **15** depicting an expanded state of a Future Aircraft lever, in accordance with certain embodiments.

FIG. **17**B is a close-up view of the expanded Future Aircraft lever shown in FIG. **17**A, in accordance with certain embodiments.

FIG. **18**A is another screenshot of the exemplary dynamic view of FIG. **15** depicting an expanded state of the Future Aircraft lever and an Operational Efficiency lever, in accordance with certain embodiments.

FIG. **18**B is a close-up view of the expanded Operational Efficiency lever shown in FIG. **18**A, in accordance with certain embodiments.

FIG. **19**A is another screenshot of the exemplary dynamic view of FIG. **15** depicting an expanded state of a Renewable Energy lever and a Market Based Measures lever, in accordance with certain embodiments.

FIG. **19**B is a close-up view of the expanded Renewable Energy lever shown in FIG. **19**A, in accordance with certain embodiments.

FIG. **20**A is another screenshot of the exemplary dynamic view of FIG. **15** depicting an expanded state of the Market Based Measures lever only, in accordance with certain embodiments.

FIG. **20**B is close-up view of the expanded Market Based Measures lever shown in FIG. **20**A, in accordance with certain embodiments.

FIG. **20**C is a close-up view of the Market Based Measures lever in a collapsed state, in accordance with certain embodiments.

FIGS. **20**D and **20**E are close-up views of the Market Based Measures levers shown in FIGS. **20**B and **20**C, respectively, with descriptive text displayed for a more options icon, in accordance with certain embodiments.

FIG. **21** is another screenshot of the exemplary dynamic view of FIG. **15** depicting a loading state, in accordance with certain embodiments.

FIGS. **22**A and **22**B are screenshots of an exemplary graphical user interface for depicting another chart view of the dynamic aviation emissions modeling tool, the chart view including the selected flight paths shown in FIG. **15**, along with the corresponding emissions data, accordance with certain embodiments.

FIG. **23** is a screenshot of an exemplary graphical user interface for depicting a welcome screen of the dynamic aviation emissions modeling tool, the welcome screen comprising various user-selectable options for interacting with the tool, including taking a tour, exploring strategies, and forecasting scenarios, in accordance with certain embodiments.

FIGS. **24**A to **24**J are screenshots of an exemplary graphical user interface for depicting a tour view of the dynamic aviation emissions modeling tool shown in FIG. **23**, in accordance with certain embodiments.

FIGS. **25**A and **25**B are screenshots of an exemplary graphical user interface for depicting an explore strategies view of the dynamic aviation emissions modeling tool shown in FIG. **23**, in accordance with certain embodiments.

FIG. **26** is a screenshot of a first exemplary chart view included in the explore strategies view of FIG. **25**A, the first chart view showing the CO2 emissions impact of a selected fleet renewal strategy, in accordance with certain embodiments.

FIGS. **27**A to **27**H are screenshots of a second exemplary chart view included in the explore strategies view of FIG. **25**A, the second chart view showing the CO2 emissions impact of various future aircraft strategies, in accordance with certain embodiments.

FIGS. **28**A to **28**B are screenshots of a third exemplary chart view included in the explore strategies view of FIG. **25**A, the third chart view showing various options for selecting operational efficiency strategies that impact CO2 emissions, in accordance with certain embodiments.

FIGS. **29**A to **29**C are screenshots of a fourth exemplary chart view included in the explore strategies view of FIG. **25**A, the fourth chart view showing the CO2 emissions impact of various renewable energy strategies, in accordance with certain embodiments.

FIGS. **30**A to **30**C are screenshots of a fifth exemplary chart view included in the explore strategies view of FIG. **25**A, the fifth chart view showing the CO2 emissions impact of various market-based measures strategies, in accordance with certain embodiments.

FIGS. **31**A and **31**B are screenshots of a first exemplary map view included in the explore strategies view of FIG. **25**A, the first map view graphically depicting user selection of an aircraft filter option, in accordance with certain embodiments.

FIGS. **32**A and **32**B are screenshots of a second exemplary map view included in the explore strategies view of FIG. **25**A, the second map view graphically depicting user selection of an airline filter option, in accordance with certain embodiments.

FIGS. **33**A to **33**K are screenshots of a third exemplary map view included in the explore strategies view of FIG. **25**A, the third map view graphically depicting user selection of various route filter options, in accordance with certain embodiments.

FIGS. **34**A and **34**B are screenshots of an exemplary graphical user interface for depicting a forecast scenarios view of the dynamic aviation emissions modeling tool shown in FIG. **23**, in accordance with certain embodiments.

FIGS. **35**A to **35**C are screenshots of an exemplary outlook view included in the forecast scenarios view of FIG. **34**A, shown in light and dark modes, in accordance with certain embodiments.

FIGS. **36**A to **36**E are screenshots of a second exemplary outlook view included in the forecast scenarios view of FIG. **34**A, the second outlook view graphically depicting user selection of various traffic growth forecast options, in accordance with certain embodiments.

FIG. **37** is a screenshot of a third exemplary outlook view included in the forecast scenarios view of FIG. **34**A, the third outlook view graphically depicting a fleet renewal option, in accordance with certain embodiments.

FIGS. **38**A and **38**B are screenshots of a third exemplary outlook view included in the forecast scenarios view of FIG. **34**A, the third outlook view graphically depicting user selection of various future aircraft options, in accordance with certain embodiments.

FIGS. **39**A and **39**B are screenshots of an exemplary annual view included in the forecast scenarios view of FIG. **34**A, the annual view corresponding to the outlook view shown in FIG. **38**A, in accordance with certain embodiments.

FIGS. **40**A and **40**B are screenshots of a fourth exemplary outlook view included in the forecast scenarios view of FIG. **34**A, the fourth outlook view graphically depicting user selection of various operational efficiency options, in accordance with certain embodiments.

FIGS. **41**A and **41**B are screenshots of a fifth exemplary outlook view included in the forecast scenarios view of FIG. **34**A, the fifth outlook view graphically depicting user selection of various renewable energy options, in accordance with certain embodiments.

FIGS. **42**A and **42**B are screenshots of a sixth exemplary outlook view included in the forecast scenarios view of FIG. **34**A, the sixth outlook view graphically depicting user selection of various market-based measures options, in accordance with certain embodiments.

FIG. **43** is a screenshot of a second exemplary annual view included in the forecast scenarios view of FIG. **34**A, the second annual view corresponding to the outlook view shown in FIG. **42**B, in accordance with certain embodiments.

FIGS. **44**A and **44**B are screenshots of additional exemplary annual views included in the forecast scenarios view of FIG. **34**A, the additional views showing pop-up screens with measurement values corresponding to percentage values displayed on the screen, in accordance with certain embodiments.

FIG. **45** is a screenshot of an exemplary map view included in the forecast scenarios view of FIG. **34**A, the map view corresponding to the annual view shown in FIG. **44**B, in accordance with certain embodiments.

FIGS. **46**A and **46**B are screenshots of exemplary map and annual views, respectively, included in the forecast scenarios view of FIG. **34**A and corresponding to a first user-selected year, in accordance with certain embodiments.

FIGS. **47**A to **47**C are screenshots of exemplary outlook, annual, and map views, respectively, included in the forecast scenarios view of FIG. **34**A, the annual and map views corresponding to a second user-selected year and the outlook view graphically depicting user selection of the second year, in accordance with certain embodiments.

FIG. **48** is a block diagram of an exemplary system capable of implementing aspects of the embodiments described herein.

FIG. **49** is a flowchart depicting an exemplary method for dynamically and interactively presenting aviation emissions information, in accordance with embodiments.

DETAILED DESCRIPTION OF EXAMPLE EMBODIMENTS

The description that follows describes, illustrates, and exemplifies one or more particular embodiments of the invention in accordance with its principles. This description is not provided to limit the invention to the embodiments described herein, but rather to explain and teach the principles of the invention in such a way to enable one of ordinary skill in the art to understand these principles and, with that understanding, be able to apply them to practice not only the embodiments described herein, but also other embodiments that may come to mind in accordance with these principles. The scope of the invention is intended to cover all such embodiments that may fall within the scope of the appended claims, either literally or under the doctrine of equivalents.

It should be noted that in the description and drawings, like or substantially similar elements may be labeled with the same reference numerals. However, sometimes these elements may be labeled with differing numbers, such as, for example, in cases where such labeling facilitates a clearer description. In addition, system components can be variously arranged, as known in the art. Also, the drawings set forth herein are not necessarily drawn to scale, and in some instances, proportions may be exaggerated to more clearly depict certain features and/or related elements may be omitted to emphasize and clearly illustrate the novel features described herein. Such labeling and drawing practices do not necessarily implicate an underlying substantive purpose. As stated above, the specification is intended to be taken as a whole and interpreted in accordance with the principles of the invention as taught herein and understood to one of ordinary skill in the art.

In this application, the use of the disjunctive is intended to include the conjunctive. The use of definite or indefinite articles is not intended to indicate cardinality. In particular, a reference to "the" object or "a" and "an" object is intended to denote also one of a possible plurality of such objects.

Existing tools for displaying emissions data for the aviation industry lack detailed analysis and dynamic depiction of the dependencies between different strategies to reduce emissions (e.g., CO2 emissions). Systems and methods described herein provide a dynamic display tool (or graphical user interface) configured to visualize various sustainability strategies in an easily discernible and interactive manner that can help improve the user's understanding of the dependencies between the strategies. In embodiments, the dynamic display tool (also referred to herein as a "dynamic aviation emissions modeling tool") includes various graphical elements, including, e.g., interactive levers, sliders, or other input devices, for representing the different sustainability strategies and for allowing selection and/or adjustment of each strategy. The dynamic display tool also includes various graphics or graphical elements for visually and dynamically depicting the environmental impact of implementing the selected strategies and the dependencies between them. For example, the dynamic tool may be used to display the impact of using hydrogen aircraft on emissions and hydrogen carbon intensity. The techniques described herein may be useful to various entities including, for example, regulators, airlines, research institutes, and other users interested in different sustainability strategies for the aviation industry and how they can mitigate CO2 emissions, interact with each other, and/or are dependent on each other.

According to embodiments, exemplary sustainability strategies or options may include: (1) fleet renewal, or changing a composition of the aircraft in the fleet (e.g., from the current A/C type to the latest A/C type), (2) future aircraft, or changing the aircraft technology used (e.g., from conventional aircraft to hydrogen aircraft, electric aircraft, or other next generation aircraft), (3) operational efficiency improvement, or assessing the total improvement in efficiency, (4) sustainable aviation fuel ("SAF"), or increasing the use of renewable energy sources (e.g., for electric aircraft, changing the electricity grid composition from fossil fuel sources to renewable energy sources: for hydrogen aircraft, changing the hydrogen carbon intensity from black to grey, blue, or green: etc.), and looking at the global SAF market share being utilized by the aviation industry, and (5) market-based measures. As will be appreciated, other sustainability strategies may be used in addition to, or instead of, the above-listed strategies, in accordance with the techniques described herein.

In the following paragraphs, these and other aspects of the dynamic display tool will be described in more detail with reference to FIGS. **1** through **47**C, which show exemplary aviation strategies graphical user interfaces ("GUIs") for implementing various aspects of the dynamic display tool on an electronic device. Some of the graphical user interfaces shown in FIGS. **1** through **47**C may be substantially similar in overall design and operation but may differ in terms of content, due to a difference in the inputs received from the user for selecting certain sustainability strategies, flights, and/or other parameters. It should be appreciated that the graphical user interfaces shown herein are merely exemplary and can comprise various other details, arrangements, and/or selectable options.

In embodiments, one or more of the GUIs may be generated or provided by a system or computing device (e.g., computing device **400** in FIG. **48**) and displayed on a display screen or other display device for presentation to the user, such as, e.g., display screen **10** shown in the figures. While the illustrated embodiments depict a GUI with a particular shape and size configured for presentation on, for example, a personal computer, laptop, or stand-alone display screen, it is contemplated that the techniques described herein can also be used to provide GUIs having other formats or configurations to accommodate other types of electronic devices and/or display screen sizes, such as, for example, tablets, smartphones, televisions, and other media devices.

All or portions of the dynamic display tool may reside on a remote computing device (e.g., server) that is in communication (e.g., via wired and/or wireless networks) with a client device of a user configured to display the GUI **100** on a display screen of the client device. User inputs received via the dynamic display tool (e.g., strategy selections) may cause or trigger a call to backend services, such as the remote server, a remote database coupled thereto, or other backend device, in order to request a data set that is tailored to the user's preferences (e.g., strategy selections).

In embodiments, the dynamic display tool may be configured, for example, using software executed by a computing device, to receive, from the backend services, aviation emissions information for a plurality of flights and a select period of time, and graphically present, via the aviation strategies graphical user interface, the aviation emissions information in association with a plurality of adjustable sustainability strategies. The dynamic display tool may be further configured to dynamically adjust the graphical presentation of one or more aspects of the aviation emissions information based on a user input for adjusting a selected strategy, as described herein. The aviation emissions information may include carbon emissions information, other emissions information, and/or any other data useful for studying and evaluating the environmental impact of the aviation industry. The aviation emissions information may include measured data collected for a past portion of the select time period (e.g., from 2019 until present day) and forecasted data determined based on projections for a future portion of the select time period (e.g., the next ten years). The forecasted data may be determined based on the measured data, expected changes over time (e.g., population growth, technological advances, etc.), predicted impacts of each sustainability strategy, and/or other relevant data.

FIG. **1** illustrates an aviation strategies graphical user interface (or GUI) **100** configured to graphically display a plurality of flights **102** in a geographic map view, or on a map of the world (also referred to herein as a "geographic map user interface"). In the illustrated embodiment, each flight **102** (or flight path) is represented by a thin line that extends between the starting point and the destination. Other depictions of the flight paths **102** are also contemplated. Also, while the illustrated map shows the whole world, it should be appreciated that the map view may be limited to smaller sections of the world in other embodiments.

The GUI **100** is also configured to display a table or chart **104** for listing select metrics related to the emissions impact of the depicted flights **102**. For example, the table **104** lists data, or metrics, for the total number of flights shown on the map, the operational fuel efficiency of those flights (e.g., in Le/100 pkm, or petrol liters equivalent per passenger per 100 kilometers (km)), the operational CO2 emissions level for those flights (e.g., in gCO_2e/pkm, or grams of CO_2 equivalent per passenger per 100 km), and net CO2 emissions (e.g., in $MtCO_2e$). In other embodiments, the GUI **100** may be configured to display additional and/or different metrics in the table **104**. In some cases, the GUI **100** may be configured to allow user selection of the units used for the displayed metrics, for example, as shown in FIG. **35**C. In general, the table **104** is configured to provide the metrics in a clear and easily discernible manner. For example, the metrics are displayed as text with a title line and a value line below it, where the value line contains the value and the unit. The GUI **100** may also be configured to display a tooltip or explanation of each metric when the user hovers over the unit depiction, for example, as shown in FIGS. **44**A and **44**B. In other embodiments, the GUI **100** may be configured to display the metrics in other, easily discernible formats (i.e. pie chart, block diagram, etc.).

FIGS. **2**-**10** illustrate various aspects of the GUI **100** in accordance with certain embodiments. FIGS. **12**A-**22**B illustrate various aspects of another graphical user interface **200** (or GUI **200**) in accordance with other embodiments. FIGS. **23**-**47**C illustrate various aspects of yet another graphical user interface **300** (or GUI **300**) in accordance with still other embodiments. Each of GUI **100**, GUI **200**, and GUI **300** may be similar to one or more of the other GUIs in at least some respects. Accordingly, the following paragraphs will only describe the aspects of GUI **300** and GUI **200** that differ from GUI **100**, for the sake of brevity.

FIG. **1** specifically displays metrics for the flights **102** without user mitigation (e.g., application of sustainability strategies, selection of filter values, etc.) and thus, depicts baseline emission values for comparison of the impact of selected sustainability strategies. Once the user makes selections or inputs via the GUI **100**, the values in table **104** will change to reflect those inputs, for example, as shown in FIG. **6**. As shown in FIG. **8**, change indicators **106** may appear next to each metric, or data line, to indicate, e.g., in percentages, if/how the value changes compared to the baseline. The color and arrow direction of the change indicator may depict whether the change is positive or negative, compared to the baseline. For example, in the illustrated embodiment, a green, downward arrow represents a positive outcome (e.g., decrease) and a red, upward arrow represents a negative outcome (e.g., increase). If the user makes a selection that results in zero flights, the table **104** may display "0" for the number of flights and blanks or dashes for the remaining metrics.

As shown in FIG. **1**, the GUI **100** also includes the phrase "A Year in the Life of Aviation" to indicate that the data in table **104** and the flights **102** shown on the map represent yearly data for a specific year or 12-month period. Referring additionally to FIGS. **2**A through **3**B, shown is an exemplary illustration of how the user can change the time period displayed in the map view by using a user-selectable time option **108** for switching or toggling between two or more time periods. In particular, when option **108** is set to "year" (i.e. as shown in FIG. **1**), the GUI **100** is configured to display yearly data for the flights in a given year (e.g., February 2019 to February 2020, as shown in FIG. **2**A). When the option **108** is set to "day," the GUI **100** is configured to display daily data for the flights in a given day (e.g., Jan. 20, 2020, as shown in FIG. **3**A). As would be expected, there is a stark difference in magnitude when comparing the number of yearly flights in FIG. **2**B to the number of daily flights in FIG. **3**B. Other changes in data may also appear, such as, e.g., the number of flight paths **102** displayed in the map and the amount of CO2 emissions displayed in the table **104**. In other embodiments, the user-selectable time option **108** may be configured to allow selection of other time periods (e.g., week, month, etc.) in addition to, or instead of, the year and day time periods. In some embodiments, changing the time option **108** from one value to the other may involve animation that mimics scrolling between values on a wheel, or other appropriate animation.

In some embodiments, the user-selectable time option **108** may be configured as shown in FIGS. **2**A to **3**B, where the text itself, e.g., "Year" or "Day," is a user selectable option. In other embodiments, for example, as shown in FIGS. **11**A to **11**D, the GUI **100** may include a user-selectable time option **208** that is configured as a button, icon, or other graphic and is further configured to display a drop-down menu **209** upon selection. For example, the time option **208** may include an arrow or other symbol to include the presence of the drop-down menu **209**. As shown in FIG. **11**C, the drop-down menu **209** can be configured to display or list a plurality of selectable time periods for changing or toggling the time period displayed in the map view, such as, e.g., a "Year" option and a "Day" option. Selecting one of the options causes the data displayed on the map view to change accordingly, as described above. Hovering over an option in the drop-down menu **209** may cause that option to be highlighted, as shown in FIG. **11**C. Once the user selects one of the drop-down options, the menu **209** may automatically close or collapse and the newly selection option may be displayed in the time option **208** icon. In both embodiments, hovering over the time option **108/208** may cause the corresponding time period (e.g., the calendar dates corresponding to the selected time period) to be displayed above the time option **108/208**, for example, as pop-up text, a comment bubble, or the like, as shown in the figures.

According to other embodiments, the GUI **300** includes a user selectable time option **308** that is configured to allow user selection of a particular time parameter, such as, e.g., a particular year from a list of years, as shown in FIG. **45**. For example, in the illustrated embodiment, the year 2050 has been selected and is displayed within the time option **308**. The time option **308** may include a drop-down menu that is similar to the menu **209** in FIG. **11**C, but lists a number of user-selectable years (e.g., **2019**, **2030**, **2045**, **2050**, etc.).

As shown in FIG. **1**, the GUI **100** further includes a plurality of filter options **110** across a top of the GUI **100**, above the map view. These filter options **110** may be used to adjust a scope of the data being displayed and therefore, the flight paths **102** depicted on the map and the metrics listed in the table **104**. In the illustrated embodiment, the filter options **110** may include an aircraft filter **112** for selecting a particular type of aircraft (or multiple types), an airlines filter **114** for selecting a particular airline, or multiple airlines (e.g., as shown in FIG. **5**), a distance filter **116** for selecting a particular distance, or distance range, for the flight paths **102** (e.g., as shown in FIG. **4**), an origin filter **118** for selecting a particular origin or starting location for the flight paths **102**, and a destination filter **120** for selecting a particular destination or ending location for the flight paths **102**. FIG. **6** illustrates a filtered version of the map view after the distance filter **116** has been set to "regional" or a distance of 500 to 1000 NM. As shown, there are fewer flight paths **102** on display in the map and fewer number of flights listed in table **104** due to the filtering, or narrower scope of data. Other values displayed in the GUI **100** are also adjusted accordingly (e.g., other values in the table **104**, etc.).

In some embodiments, for example, as shown in FIG. **5**, the airlines filter **114** can include a search bar, or other text input area, for enabling a user to enter a search term or phrase, such as, e.g., the name of a particular airline that the user wants to use for filtering the data. If no text is entered in the search bar, a list of all existing airlines may be displayed below the airlines filter **114** (e.g., as a drop-down menu), for example, upon selecting, or otherwise activating, the airlines filter **114** icon or graphic. Each airline name may be displayed as a separate user-selectable option **115** that has, for example, a check box or other graphic configured to enable selection, or deselection, of the airline option **115**. As the user enters the search term into the search bar, one or more matching airline options **115** may appear in a list or drop-down menu below the search bar. The user can select one or multiple airline options **115** for filtering purposes. The default filter setting may be selection of all airlines worldwide (i.e. no filtering). Thus, if none of the airline options **115** are selected, the data displayed in the map view will not be filtered. In some cases, all of the airlines options **115** may be pre-selected as a default filter setting, such that the user must de-select the airlines **115** that they do not wish to include in the displayed data.

In other embodiments, for example, as shown in FIGS. **12**A to **12**E, the GUI **200** may be configured to include an airlines filter **214** that includes an "All Airlines" option **215** to allow easy selection, or deselection, of all airlines worldwide, in addition to a search bar for entering a search term or phrase, such as, e.g., the name of a particular airline. The All Airlines option **215** may be pre-selected as a default filter setting for the map view data, as shown in FIG. **12**A. If the user wishes to filter by one or more specific airlines, the user can enter a search term and/or the airline's name in the search bar to pull up the specific airline(s). As the user types or enters the search term, a list of possible matches may be dynamically displayed below the All Airlines option **215**, as shown in FIG. **12**B. The possible matches (or proposals) may be configured as user-selectable options, like the plurality of airlines options **115** in FIG. **5** and/or the All Airlines option **215**.

In embodiments, once the user selects one of the proposed options, the selected option may be moved from the proposals list to a selected list, such as, for example, the list just below the All Airlines option **215** in FIG. **12**C. In addition, the All Airlines option **215** may be automatically deselected once a specific airlines option is selected, as shown in FIG. **12**C. The number of airlines options included in the selected list may increase as more and more airlines are selected from the proposals list, or vice versa. If all of the proposed airlines are selected, the proposal area may become a blank space, or may be configured to state "No Airlines Found," as shown in FIG. **12**D. Once specific airlines are selected, the text or description displayed in the airlines filter **214** area may be updated accordingly. For example, as shown in FIGS. **12**C to **12**D, the airlines filter **214** area may change from displaying "Airlines" to displaying the name of one or more of the selected airlines (e.g., "Delta . . . " in FIG. **12**C) and/or an indication of how many other airlines are selected (e.g., "(+2)" in FIG. **2**D).

The selected list of airlines can be configured to stay as is until the options are manually deselected by the user, or the selected list is reset due to user selection of the All Airlines option **215**. This enables the user to enter a new search term and add more airlines to the selected list, without affecting or deleting the previously selected list of airlines, if so desired. For example, as shown in FIG. **12**E, a new search phrase may be entered into the search bar while keeping the selected list of airlines as is. If the user decides to clear the selected list and generate a new list of selections based on a new search term, the user can do that as well by selecting the All Airlines option **215** to reset the filter settings.

According to other embodiments, for example as shown in FIG. **25**A, the GUI **300** may include a plurality of filter options **310** that are somewhat differ from the filter options **110**. In particular, as shown in FIGS. **31**A and **31**B, the filter options **310** may include an aircraft filter **312** with a user-selectable option (e.g., drop-down menu) for selecting one or more types of aircrafts, like the aircraft filter **112**. And as shown in FIGS. **32**A to **32**B, the filter options **312** may also include an airlines filter **314** with a user input area for enabling the user to enter a search term or phrase, such as, e.g., the name of a particular airline, and/or a list of user-selectable airlines options, like the airlines filter **114** and/or the airlines filter **214**.

Unlike the filter options **110**, however, the GUI **300** may include a route filter **360** for selecting a particular route or region for filtering the plurality of flight paths **102** shown on the map, as shown in FIGS. **33**A to **33**K. The route filter **360** may be included in place of, or in addition to, the distance filter **116**, the origin filter **118**, and/or the destination filter **120**, for example. In the illustrated embodiment, upon user selection of the route filter **360**, the GUI **300** is configured to provide (or display a drop-down menu comprising) two user-selectable options **362** for filtering the flight paths, such as, e.g., a first option **362***a* for selecting flights within, to, and from a single region, and a second option **362***b* for selecting flights between two specific regions.

As shown in FIGS. **33**B to **33**D, user selection of the first option **362***a* causes a user-selectable region option **364** to appear, and selection or expansion of the region option **364** causes a list of user-selectable regions **365** to be displayed below the two options **362** and/or in place of, or on top of, the region option **364**. Once a specific region is selected from the list of regions **365**, the selected region may be displayed in the region option **364** and an "Apply Filter" option **366** may appear, or become activated (e.g., user-selectable), within the route filter **360**.

Once the route filter **360** is applied, the drop-down menu(s) may close and an applied filter window **367** may appear. As shown in FIG. **33**E, the applied filter window **367** can be configured to display any applied filters and provide a user-selectable option to remove one of the applied filters, or reset all filters. As can be seen from FIGS. **33**E to **33**F, the flight paths **102** displayed on the map view may be adjusted based on the routes selected using the routes filter **360**, e.g., so that only the flight paths **102** within the selected route are displayed on the map view.

As shown in FIGS. **33**G, user selection of the second option **362***b* causes two region options **368** to appear for selecting a particular range of geographical areas for flight path filtering purposes. User selection of either region option **368***a*, **368***b* causes a corresponding user-selectable list of regions **369** to appear (e.g., as a drop-down menu), for example, as shown in FIG. **33**H. Once a region is selected from the list **369**, the drop-down menu may close or collapse, and the selected region may be displayed in the corresponding region option **368***a*, **368***b*, for example, as shown in FIGS. **331** and **33**J. Once both regions are selected or populated, the Apply Filter option **366** may be activated, selection of which may cause the flight paths **102** displayed on the map view to be correspondingly filtered and the applied filter window **367** to be displayed, as shown in FIG. **33**K.

Referring back to FIGS. **1** and **6**, the GUI **100** also includes a user-selectable view option **122** for changing the map view to a chart view. The user-selectable view option **122** may include one or more icons, text, or any combination thereof for representing its underlying function. In some cases, selection of the option **122** may cause the map view to fade to the background, so that the chart view can be displayed on top of the map view, for example, as shown in FIGS. **7**-**9**. In other cases, the chart view may be displayed on the GUI **100** in place of the map view. As shown in FIG. **7**, the view option **122** changes to "map view" when the GUI **100** is configured to display the chart view, such that selection of the view option **122** in FIG. **7** would cause the chart view to be replaced with the map view (i.e. switch back to FIG. **6**).

As shown in FIG. **7**, the chart view includes a baseline CO2 emissions graphic **124** that displays a baseline CO_2e emissions percentage (i.e. 100%) for the flight paths **102** displayed in the map view and a numerical baseline value for the same emissions data (e.g., 128 Mt). In embodiments, the baseline graphic **124** is a static gray bar that extends full length, or across an assigned area of the GUI **100**, and remains as shown, even as other parts of the chart view change dynamically, as described herein.

As also shown in FIG. **7**, the chart view further includes a plurality of user-selectable strategy graphics **126** (also referred to as "levers") configured to enable the user to select and/or adjust respective sustainability strategies for reducing CO2 emissions of the flight paths **102** selected in the map view. The strategy graphics **126** are initially shown only as headlines with icons and short explanatory text below each. The chart view may display only the baseline graphic **124** and the initial headlines and/or text for the graphics **126** until the user selects one of the strategy graphics **126** or otherwise activates a given strategy.

As shown in FIG. **8**, the chart view further includes a bar chart **128** (also referred to as a "waterfall chart") configured to graphically depict a predicted impact on CO2 emissions for each sustainability strategy selected using the strategy graphic **126**. The bar chart **128** may include a one or more colored bars for visually representing the reduction in CO2 emissions caused by introduction of the corresponding sustainability strategy, as described herein. The bar chart **128** may appear once the user selects one of the strategy graphics **126** and/or adjusts a parameter of the selected graphic **126**.

Once the bar chart **128** is displayed, a net emissions graphic **129** may be displayed below the bar chart **128** in order to show the overall remaining CO2 emissions, or net CO_2 emissions, after implementing the selected sustainability strategy. The net emissions graphic **129** may be presented as a gray bar, like the baseline graphic **124**, with a length or size selected based on the net amount of emissions remaining after introduction of the selected strategy. For example, a length of the gray bar shown in the net emissions graphic **129** plus the lengths of any colored bars in the bar chart **128** may equal a total length of the gray bar shown in the baseline graphic **124**. The net emissions graphic **129** may also include a textual display of a numerical percentage value and a total amount (in Mt) of the reduction. The GUI **100** may also dynamically display or depict the CO2 emissions impact of the selected strategies in other areas as well, such as, e.g., the metrics shown in the table **104**.

In various embodiments, each of the strategy graphics **126** includes a slider for selecting and/or adjusting one or more parameters associated with the corresponding sustainability strategy. In general, the sliders are configured to provide visual indication of adjustable content associated with the reduction strategies and enable the user to increase or decrease the parameter values by moving the slider along a horizontal scale or track. In embodiments, each slider is associated with a corresponding bar of the bar chart **128**, such that adjusting the sliders has a direct and dynamic effect on the bar chart **128**. For example, each of the bars of the bar chart **128** may be configured to increase or decrease in size (or emissions reduction value) depending on the parameter value selected for the corresponding strategy using the associated slider. The bar chart **128** may also be configured to display the actual reduction in CO2 emissions caused by each strategy as a numeric percentage or other numeric value. In other embodiments, other input devices may be used in place of the sliders, such as, e.g., for example, user-selectable buttons, radio buttons, dials, drop-down menus, data entry fields, and more. Such input devices can be similarly linked to the bar chart **128** in order to directly and dynamically depict the CO2 emissions impact of each strategy.

As shown in FIGS. **8**, **9**A, and **9**B, the plurality of strategy graphics **126** and the bar chart **128** may be color coded, so that the impact of each strategy, or the connection between inputs and outputs in the chart view; is easily discernible to the user. For example, each strategy graphic **126** may be assigned a different color, and the sub-strategies belonging to the same category may be presented in the same color. While a specific color code may be shown in the figures, it should be appreciated that other colors, or color codes, may be used instead, in accordance with the principles described herein. In some embodiments, the GUI **100** may use shading instead of colors, or other types of codes for visually connecting the strategy selections to the emissions impacts.

In the illustrated embodiment, the plurality of strategy graphics **126** may include a fleet renewal graphic **130**, a future aircraft graphic **132**, an operational efficiency graphic **134**, a renewable energy graphic **136**, and a market-based measures graphic **138**. In other embodiments, the strategy graphics **126** may include other and/or additional graphics for representing alternative and/or additional sustainability strategies.

According to embodiments, the fleet renewal graphic **130** may be configured to enable the user to see the emissions impact of replacing older aircraft (or "A/C") with the latest aircraft available, such as, e.g., aircraft that incorporates the latest advancements in aerodynamics, propulsion, systems, and materials. For example, as shown in FIG. **8**, the fleet renewal graphic **130** may be configured to allow user-selection of a desired strategy for fleet renewal by providing a first user-selectable slider **130***a*, or other input device, that is movable along a first scale **130***b* having a first parameter value corresponding to current or older aircrafts (e.g., "current A/C type") and a second parameter value corresponding to newer or latest aircrafts (e.g., "latest A/C type"). The location of the fleet renewal slider **130***a* on the first scale **130***b* may indicate the amount of latest aircraft technology that will be part of the user's fleet renewal strategy. For example, placing the slider **130***a* at the first parameter value indicates no fleet renewal, while placing the slider **130***a* at the second parameter value (i.e. as shown in FIG. **8**) indicates a complete fleet renewal. In some embodiments, moving the fleet renewal slider **130***a* to the middle of the scale **130***b* may indicate selection of a fleet that is comprised of about 50% current technology aircraft and about 50% latest technology aircraft.

As shown in FIG. **8**, a first colored bar **128***a* of the bar chart **128** may be configured to display the CO2 emissions impact, or a reduction in the CO2 emissions percentage, that is caused by the fleet renewal strategy selected using graphic **130** (e.g., selection of current A/C, latest A/C, or a combination thereof). For example, the first bar **128***a* may have a size that directly correlates to, or represents, the amount of emissions reduction caused by the selected fleet renewal strategy. A numerical representation of the resulting reduction in CO2 emissions (e.g., percentage of reduction) may also be displayed, as illustrated. The first bar **128***a* may be colored a first color to match a first color of the fleet renewal graphic **130** (e.g., purple).

The future aircraft graphic **132** may be configured to enable the user to see the emissions impact of incorporating future or next generation airframe, systems, and energy and propulsion technology that may be more climate-friendly than existing technologies. According to embodiments, the graphic **132** may include a plurality of tabs for selecting different types of future technology. For example, in the illustrated embodiment, the future aircraft graphic **132** includes a conventional tab **132***a* for selecting advanced conventional aircraft technology, or aircraft that burn jet fuel for propulsion but with increased efficiency: a hydrogen tab **132***b* for selecting a hydrogen platform, or aircraft that burn hydrogen for propulsion; and an electric tab **132***c* for selecting a battery-electric platform, or aircraft that use electricity for propulsion.

The future aircraft graphic **132** also includes a plurality of drop-down or expandable options (or "cards") for specifying or selecting certain parameters associated with the selected technology tab **132***a*, **132***b*, or **132***c*. In the illustrated embodiment, the expandable options are for selecting aircraft types, such as, for example, a regional aircraft option **132***d*, a single-aisle aircraft option **132***e*, and a twin-aisle aircraft option **132***f*, e.g., as shown in FIGS. **8** and **9**A. In some cases, one or more of the aircraft options will be removed if the selected technology tab does not support or have the aircraft option(s). For example, when the electric tab **132***c* is selected, only the regional aircraft option **132***d* may be shown, whereas all three options **132***d*, **132***e*, and **132***f* may be displayed for the conventional tab **132***a* and the hydrogen tab **132***b*.

Selecting one of the options **132***d*, **132***e*, or **132***f* may cause the GUI **100** to display additional sliders for selecting and/or adjusting specific parameter values associated with the selected aircraft type. For example, as shown in FIG. **9**B, a market share slider **132***g* may be displayed and configured for selecting the percentage or number of older aircraft that will be replaced by the selected type and size of newer aircraft (e.g., 0 to 100%). A range capability slider **132***h* may also be displayed for indicating the distance that the selected aircraft can travel (e.g., 0) to 1000 NM). The values displayed on the scale associated with the range capability slider **132***h* may vary depending on the selected aircraft.

The dynamic tool may be configured to calculate the change in CO2 emissions due to the selected future aircraft strategy by determining the number of future aircraft flights that will be required to replace historic or current flights. This determination may take into account the seat count and flight frequency of current flights to determine how many future aircraft flights will be needed to replace the same number of seats. In addition, the number of historic seats that will be replaced may be computed based on the user-defined market share, i.e. as selected using market share slider **132***g*.

The above calculation assumes that current aircrafts of regional size will be replaced with future aircrafts of regional size. In order to allow the user to change the future aircraft size, the market share slider **132***g* may be associated with one or more sub-sliders **140** that may be displayed (or drop-down) upon expanding the market share slider **132***g*, for example, as shown in FIG. **9**B. The sub-sliders **140** may be used to change the market share for the selected aircraft size, or the number of flights being carried out by the selected aircraft size, or other parameters associated therewith. In the illustrated embodiment, a first sub-slider **140***a* is for selecting a market share for single aisle aircraft, and a second sub-slider **140***b* is for selecting a market share for twin-aisle aircraft. The values selected using the sub-sliders **140***a* and/or **140***b* may be reflected in the future aircraft graphic **132** next to the corresponding option **132***d*, **132***e*, and/or **132***f*, for example, as shown in FIG. **9**A.

As shown in FIGS. **8** and **9**A, a second colored bar **128***b* of the bar chart **128** may be configured to display the CO2 emissions impact of the future aircraft strategy selected using graphic **132** (e.g., selection of conventional, hydrogen, or electric technology, and specific parameters for each). For example, the second bar **128***b* may have a size that directly correlates to, or represents, the amount of emissions reduction caused by the selected future aircraft strategy. A numerical representation of the resulting reduction in CO2 emissions (e.g., percentage of reduction) may also be displayed, as illustrated. The second bar **128***b* may be colored a second color to match a second color of the future aircraft graphic **132** (e.g., blue).

The operational efficiency graphic **134** may be configured to enable the user to see the emissions impact of having more efficient flights, routes, and networks as a result of optimized weights, advanced air-traffic management ("ATM") systems, and improved load factors, for example. As shown in FIG. **8**, the operational efficiency graphic **134** may be configured to allow user-selection of a desired amount of total improvement by providing a second user-selectable slider **134***a*, or other input device, that is movable along a second scale **134***b* having a first parameter value corresponding to zero, or no improvement of current conditions, and a second parameter value corresponding to ten, or maximum improvement of current conditions. Thus, the location of the operational efficiency slider **134***a* on the second scale **134***b* may indicate the amount of operational efficiency improvement that will be part of the user's strategy.

As shown in FIG. **8**, a third colored bar **128***c* of the bar chart **128** may be configured to display the CO2 emissions impact of the operational efficiency strategy selected using graphic **134** (e.g., the amount of improvement selected). For example, the third bar **128***c* may have a size that directly correlates to, or represents, the amount of emissions reduction caused by the selected operational efficiency strategy. A numerical representation of the resulting reduction in CO2 emissions (e.g., percentage of reduction) may also be displayed, as illustrated. The third bar **128***c* may be colored a third color to match a third color of the operational efficiency graphic **134** (e.g., red).

The renewable energy graphic **136** may be configured to enable the user to see the emissions impact of using energy and/or fuel that is derived from non-fossil pathways. Exemplary forms of renewable, on-board energy storage may include sustainable aviation fuels ("SAF"), green hydrogen, batteries, and/or others. As shown in FIG. **9**A, the graphic **136** may include a plurality of user-selectable sliders disposed on respective scales for selecting parameter values for different types of renewable energy and/or fuel, such as, for example, an electricity grid composition slider **136***a* for selecting whether the electricity used is derived from all renewable resources, all fossil-based resources, or some combination thereof. The graphic **136** may also include a hydrogen carbon intensity slider **136***b* for selecting whether the hydrogen source is green, blue, gray, or black. The graphic **136** may also include a global SAF market share slider **136***c* for selecting a global or total market share (e.g., 0 to 100%) for aircraft that use sustainable aviation fuels.

As shown in FIG. **9**A, one or more of the sliders, such as, e.g., the electricity grid composition slider **136***a*, may include a plurality of markers **137** disposed at various locations along the scale for indicating certain parameters or values. In some embodiments, as shown in FIGS. **22**A and **22**B, the one or more sliders, such as, e.g., the electricity grid composition slider **236***a*, may be configured to display descriptive text **239** when the user hovers over a given marker **237**, or moves the slider to the marker position. In FIG. **22**B, the descriptive text **239** states "natural gas" to indicate that the slider **136***a* has been moved to the marker **237** corresponding to selection of natural gas as the renewable energy source.

As shown in FIG. **9**A, a fourth colored bar **128***d* of the bar chart **128** and may be configured to display the CO2 emissions impact of the renewable energy strategy selected using graphic **136** (e.g., relative selections for renewable electric energy sources, green hydrogen, or SAF). For example, the fourth bar **128***d* may have a size that directly correlates to, or represents, the amount of emissions reduction caused by the selected renewable energy strategy. A numerical representation of the resulting reduction in CO2 emissions (e.g., percentage of reduction) may also be displayed, as illustrated. The fourth bar **128***d* may be colored a fourth color to match a fourth color of the renewable energy graphic **136** (e.g., yellow).

The market-based measures graphic **138** may be configured to enable the user to see the emissions impact of market-based measures, such as, for example, carbon offsets, which reduce or remove greenhouse gases from sectors outside of aviation to offset the emissions produced by aviation. In some cases, the carbon offsets may be due to implementing climate-friendly routing for a significant portion of the fleet in a short amount of time.

As shown in FIG. **9**A, a fifth colored bar **128***e* of the bar chart **128** and may be configured to display the CO2 emissions impact of the market-based measures strategy selected using graphic **138**. For example, the fifth bar **128***e* may have a size that directly correlates to, or represents, the amount of emissions reduction caused by the selected market-based measures strategy. A numerical representation of the resulting reduction in CO2 emissions (e.g., percentage of reduction) may also be displayed, as illustrated. The fifth bar **128***e* may be colored a fifth color to match a fifth color of the market-based measures graphic **138** (e.g., green).

In various embodiments, the dynamic display tool may be configured to depict dependency between a certain combination of sustainability strategies (or levers), such as, for example, dependency between fleet renewal and future aircraft, fleet renewal and sustainable aviation fuel, fleet renewable and operational efficiency, renewable energy and sustainable aviation fuel, renewable energy and future aircraft, and/or future aircraft and operational efficiency. For example, adjusting the future aircraft graphic **132** to include more latest aircraft technology may automatically change an outcome (e.g., amount of CO2 emissions) of the renewable energy graphic **136**, as well as the percentage number displayed in association therewith, because of the dependency between the two strategies. In particular, using more latest technology aircraft may reduce the impact of electric aircraft or other future aircraft types at least because the latest technology aircraft may be more fuel efficient than the conventional aircraft that they are replacing. The dependencies may be shown as automatic changes to the CO2 emissions data being displayed on the GUI **100** (e.g., in the bar chart, as metrics, in sliders, etc.), or in any other suitable manner, as will be appreciated.

In various embodiments, the GUI **100** further includes a dynamic mode option **144** for changing from the map view or chart view to a dynamic mode of the GUI **100**, for example, as shown in FIG. **10**. The dynamic mode option **144** may be a slider-type button or other input device for toggling or turning the dynamic mode on and off. When the dynamic mode is selected (e.g., option **144** is slid to the right), the map view/chart view may be replaced with a carbon emission outlook graph **150**, as shown in FIG. **10**. When the dynamic mode is unselected (e.g., option **144** is slid to the left), the graph **150** may be replaced with the chart view or the map view, depending on which view was last selected via the view option **122** and/or which view is currently reflected by the view option **122** (e.g., the map view in FIG. **10**).

As shown in FIG. **10**, the carbon emissions outlook graph **150** graphically depicts the impact of various measures, or sustainability strategies, on the reduction of carbon emissions, or CO2 emissions, over a select period of time. The measures may be based on preselected and/or user-selected scenarios, and their impact may be depicted using stacked colored bars for each year. The colored bars may be stacked on top of a gray bar that represents the remaining CO2 emissions for that year. The select period of time may be pre-selected or user-selected, for example, using a time-select slider **151** as shown in FIG. **10**, and may include past and/or future time periods. Thus, the graph **150** can be configured to graphically and dynamically depict the emissions trend, or outlook, over a number of years for selected scenarios.

In various embodiments, the graph **150** may be configured to display carbon emissions information for measures that are the same as, similar to, based on, or otherwise associated with the sustainability strategies shown in the chart view, and may use the same, or similar, color coding as the chart view for consistency and ease of connection. The measures depicted in the graph **150** may be represented by a corresponding lever that operates like the levers shown in FIG. **9**A, and described herein, to adjust or configure one or more parameters associated with the underlying measure. While the levers are shown as sliders in the depicted embodiments, it should be appreciated that other input mechanisms may be used to enable user configuration of the sustainability strategies and measures described herein.

As shown in FIG. **10**, the GUI **100** may include, for example, a traffic growth forecast lever **152** that may be set to low, medium, or high using a traffic growth slider: a fleet renewal lever **154** that may be associated with the fleet renewal graphic **130** and may be set to none, nominal, or aspirational using a fleet renewal slider: a future conventional aircraft lever **156** that may be associated with the conventional aircraft option **132***a* and may be set to none, evolutionary, or revolutionary using a conventional slider: an electric and hydrogen aircraft lever **158** that may be associated with the electric aircraft option **132***c* and the hydrogen aircraft option **132***b* and may be set to none, moderate, or large-scale using an electric and hydrogen slider: an operational efficiency improvement lever **160** that may be associated with the operational efficiency graphic **134** and may be set to none, nominal, or aspirational using an efficiency slider: a sustainable aviation fuel lever **162** that may be associated with the global SAF market share slider **136***c* and may be set to low, moderate, or aspirational using an SAF slider; and a market-based measures lever **164** that may be associated with the market-based measures graphic **138** and may be set to none, moderate, or high using a market slider.

In some embodiments, the GUI **100** may also include, in the dynamic mode, a master scenario option **166** configured to allow the user to select a particular scenario for which carbon emissions data is displayed on the graph **150**. Each scenario includes specified selections, or slider settings, for each of the levers (or underlying measures) and/or certain parameters associated therewith. The scenarios may be manually entered by the user or uploaded from a saved file (e.g., using the "load scenario" option). In FIG. **10**, the depicted measures have been configured according to a custom user scenario that sets median values, or slider settings, for each of the levers. When a new scenario is entered via adjustment of a measure or parameter value, or other change in data scope, the carbon emissions data may be re-calculated and the graph **150** updated accordingly.

In other embodiments, each of the depicted measures, or strategies, may have a master lever for limited configuration of the corresponding measure, and a number of the master levers may have one or more corresponding detailed levers, or sliders, for more nuanced configuration of the corresponding measure, as shown by GUI **200** in FIGS. **13**A to **21**. The GUI **200** can be configured to include an overview **201** that displays or lists all available master levers, as best seen in FIG. **13**B. In the illustrated embodiments, the GUI **200** includes six master levers, namely: a traffic growth forecast lever **252**, fleet renewal lever **254**, future aircraft lever **256**, operational efficiency lever **258**, renewable energy lever **260**, and market-based measures lever **262**, similar to the corresponding levers of GUI **100**. In other embodiments, the GUI **200** may include more or fewer master levers, as will be appreciated.

As shown in FIGS. **16**A to **20**E, one or more of the master levers may be configured to display a detailed view, or corresponding detailed lever(s), upon user selection of the master lever, or other aspect of the GUI **200**. In some embodiments, for example, as shown in FIG. **13**B, each master lever with more settings can be configured to display a user-selectable "more options" or "detail settings" icon **259** that is placed adjacent to, or above, the corresponding slider, and is configured to display the detailed levers in response to user selection of the icon **259**. For example, selection of the icon **259** for a given master lever may cause the master lever to expand into or otherwise reveal detailed levers. In some cases, the detailed levers may be displayed in place of, or below, the master lever, and may cause the other master levers to shift down or up, as needed, to accommodate the detailed levers, as shown in FIGS. **16**A, **17**A, **18**A, **19**A, and **20**A, for example. In other cases, selection of the icon **259** may cause display of a drop-down menu that includes the detailed levers and at least partially overlaps with one or more other levers. The detailed levers may be arranged vertically, or stacked on top of each other, for example, as shown in FIG. **20**B, or in any other suitable arrangement. In the illustrated embodiment, for example as best seen in FIG. **13**B, all of the levers except the fleet renewal lever **254** include the icon **259** because the fleet renewal lever **254** does not have associated detailed levers. As shown in FIG. **15**, the fleet renewal lever **254** can be adjusted using the corresponding slider displayed in the lever overview menu **201**. In other embodiments, the fleet renewal lever **254** may also be configured to include one or more detailed levers and thus, may include the icon **259**.

For improved usability, hovering over the more options icon **259** may cause descriptive text **259***a*, such as, e.g., "Detail Settings," to be displayed above or adjacent to the icon **259**, for example, as shown in FIG. **20**E. When in the detailed levers view, the more options icon **259** may be replaced with a return icon **259***b* for enabling the user to return back to the master overview **201**, for example, as shown in FIG. **20**D. As also shown, descriptive text **259***c*, such as, e.g., "Back to Master," may be displayed above or adjacent the icon **259***b*, for example, when the user hovers over the icon **259***b*. As another example, according to embodiments, the GUI **300** may be configured to display explanatory text in a pop-up window, or other appropriate interface, when the user hovers over a given prompt, such as, e.g., "How do I read this chart?" in FIG. **39**B.

The master lever can be configured to enable the user to assess the impact of the corresponding strategy based on generalized settings, such as, e.g., "Low," "Moderate," and "High," as shown by GUI **200** in FIG. **13**A. In the illustrated embodiment, all of the master levers are set to "Moderate," or other median value, as a default setting. From there, the user may move a slider of a given master lever left towards the "Low" setting, or right towards the "High" setting, as desired. In this manner, the master levers can be manipulated by novice or inexperienced users without needing detailed knowledge about the underlying logic to understand and use the sliders.

In some embodiments, the master levers may be mapped to the detailed levers to enable more experienced, or expert, users to customize one or more advanced settings for the corresponding measure. In some cases, the detailed levers enable user selection of a specific numerical value or range, while the corresponding master lever has generic or categorical settings (e.g., Low, Moderate, High), for example, as shown in FIGS. **17**A and **17**B. As shown in FIGS. **16**A to **20**B, the exact type of detailed lever(s) provided for each master lever may vary depending on the type of measure represented by the corresponding master lever.

In some embodiments, the detailed-levers view may include tabs or other user-selectable options for switching between different scenarios or modes of calculation, such as, e.g., a custom scenario (e.g., via selection of "Custom" option **252***a* in FIG. **16**B), a fixed or precomputed scenario (e.g., via selection of "BoeingCMO" option **252***b* in FIG. **16**C, or "CORSIA" option in FIG. **20**B), and/or one or more other scenarios, such as, e.g., a scenario that displays a different set of detailed levers, other proprietary scenario, a user's preset forecast or scenario, etc. As shown in FIGS. **20**B and **20**D, for example, when the custom mode is selected, the detailed levers **262***a*, **262***b*, and **262***c* can be configured to enable a user to customize the settings of the selected scenario, or otherwise create a new scenario, for example, by allowing adjustment of one or more of the detailed levers. As shown in FIG. **16**C, for example, when the precomputed mode is selected, the detailed levers may be set to preselected values that correspond to a preset sustainability scenario and may be configured to prevent the user from adjusting the lever settings further (e.g., as shown by the grayed out, or unselectable, slider in FIG. **16**C).

In some embodiments, each detailed lever may be configured to enable the user to adjust the corresponding setting across its full range (e.g., 0 to 100%), while each master lever may be configured to enable user adjustment of the corresponding measure within a limited range (e.g., 20 to 80%). For example, the master lever scale may have a smaller numerical range than the scale(s) of its detailed lever(s). Such configuration may facilitate and improve a user's understanding of the carbon emissions outlook graph **150** and related materials, for example, by reducing the number of tick marks shown on the scales in the master overview **201**. However, since the detailed levers have a wider range than the underlying master lever, the scale of a given master lever may not encompass the values selected for its corresponding detailed lever(s). In such cases, the master lever may be configured to indicate an out-of-bounds selection on its slider, for example, by including an arrow on a far left end of the slider scale, as shown in FIG. **20**C. As also shown, a given master lever may include a reset option that is displayed on or near the slider for resetting the master lever to a default value. According to some embodiments, for example, as shown in FIG. **36**B, the GUI **300** may include a master reset option (or "Reset Scenario") configured to enable the user to reset all sliders or strategies to default values. In such cases, the reset option may remain inactive or grayed out when no filter options are selected or activated, and may change to colored and/or selectable format after one or more filter options are selected or implemented.

In some cases, the arrow may be displayed on the left-side of the master slider when one or more of its detailed levers is below a lower boundary of the corresponding master lever. In other cases, the out-of-bounds arrow may be displayed on a far right end of the slider scale, for example, to indicate selection of custom settings that go beyond the high end of the master lever range. In cases where the detailed levers are a mix of in-range and out-of-range values, the GUI **200** may be configured to determine which of the detailed levers has the largest impact on the corresponding measure, or is the most dominate factor, and may use the location of that detailed lever to select a corresponding location for the slider of the master lever.

Referring now to FIGS. **14**A to **14**E, shown is an exemplary carbon emissions chart **250** configured to graphically display data for a select number of years using the techniques described herein. The chart **250** comprises a plurality of vertical columns or bars **251**, each column **251** corresponding to a particular year. In some embodiments, hovering over, or otherwise selecting, a given column **251** causes that column **251** to become grayed out (as shown in FIG. **14**A), and causes a pop-up window **255** to be displayed on top of, or at least partially overlapping the chart **250** (as shown in FIG. **14**B). The pop-up window **255** displays data specific to the selected year, for example, as shown in FIG. **14**D. The displayed data may include, for example, performance indicators that show the impact of the current master lever settings on emissions (in $MtCo_2e$) and/or operational metrics (e.g., number of flights, fuel efficiency, etc.) for the selected year. In the illustrated embodiment, the pop-up window **255** also includes a number of tabs for toggling between different sets of data for the selected year, such as, e.g., a "Metrics" tab **255***a* and an "Impact" tab **255***b*, as shown by the flow from FIG. **14**B to **14**C (see also, FIGS. **14**D and **14**E for close-up views of the window **255**). The pop-up window **255** enables the user to see year-specific information and jump from year to year, all while viewing the larger carbon emissions chart **250**.

According to other embodiments, the GUI **300** may be configured to display detailed data, or aviation metrics, for a selected year in a summary table **355** that is presented below a carbon emissions chart **350** of an outlook view presented in the forecast scenario view, for example, as shown in FIG. **37**. That is, instead of displaying the pop-up window **255** on top of the chart **250**, the GUI **300** can display the same, or similar data, in a fixed table that does not overlap with, and possibly block view of, the carbon emissions chart **350**. The data displayed in the summary table **355** may be automatically updated each time a new year is selected, e.g., using one of the user-selectable bars **351** of the chart **350**.

FIG. **21** shows an exemplary screenshot of the GUI **200** while data is loading onto the display device. As shown, the carbon emissions chart **250** may be at least slightly grayed out while the data is being loaded. Once that upload is complete, the chart **250** may return to its full color. As an example, the grayed-out chart **250** shown in FIG. **21** may be an intermediary view that is displayed after the user moves the Fleet Renewal lever **254** from the moderate setting to the low setting, or otherwise represents the GUI **200** transitioning from the chart **250** shown in FIG. **13**A, where all of the levers have default settings, to the chart **250** shown in FIG. **15**, where the slider for the Fleet Renewal lever **254** is in the low setting. In some embodiments, for example as shown in FIG. **36**D, an icon for indicating "loading" or processing" may also be displayed on top of the grayed out information while the display data is loading. In other embodiments, only the icon may be displayed to indicating loading and the rest of the screen may remain in full color (e.g., not be grayed out).

Referring now to FIG. **23**, the GUI **300** may include a welcome screen with one or more user-selectable options to help the user navigate the dynamic aviation emissions modeling tool. For example, user selection of a tour option, or "Take a Tour," opens or initiates a graphical user interface for displaying a virtual tour of the dynamic display tool that includes a description of the tool's unique features and how to use the tool, as shown in FIGS. **24**A to **24**J. As another example, user selection of a strategies option, or "Explore Strategies," opens a graphical user interface for creating a custom sustainability strategy, or otherwise exploring sustainability strategies, as shown in FIGS. **25**A to **33**K. The welcome screen also includes, for example, a forecast option, or "Forecast Scenario," user selection of which opens a graphical user interface for building a scenario and seeing its impact on emissions through **2050**, as shown in FIGS. **34**A to **47**C.

As shown in FIG. **25**A, the GUI **300** may include user-selectable navigation options **380** for switching between, or selecting either of, an explore strategies view and a forecast scenario view, to allow the user to easily transition between the two sections of the GUI **300**, without going back to the welcome screen, for example.

As also shown in FIG. **25**A, the explore strategies view of the GUI **300** may include user-selectable view options **382** for toggling between, or respectively selecting, a chart view and a map view that corresponds to the chart view (or vice versa). For example, the chart view shown in FIG. **30**A corresponds to the map view shown in FIG. **31**A, and the user may move or toggle between the two views by selecting the appropriate view option **382**. According to embodiments, FIGS. **25**A to **30**C illustrate exemplary chart views of the GUI **300** that are at least somewhat similar in operation and design to the chart views shown in FIGS. **7** to **9**A and/or FIGS. **22**A and **22**B, while FIGS. **31**A to **33**K illustrate exemplary map views of the GUI **300** that are at least somewhat similar in operation and design to the map views shown in FIGS. **1**, **6**, and **7**, as will be appreciated.

As shown in FIG. **34**A, the forecast scenario view of the GUI **300** may include a second set of user-selectable view options **384** for toggling between, or respectively selecting, an outlook view, an annual view, and a map view that corresponds to the annual view (or vice versa). For example, the annual view shown in FIG. **47**B corresponds to the map view shown in FIG. **47**C, and the user may move or toggle between the two views by selecting the appropriate view option **384**. In embodiments, the outlook view may be configured to show CO2 emissions and other related data for a plurality of years (e.g., 2019 to 2050), while the annual and map views may be configured to show the same types of data for an individual year. The user may select the year that is displayed in the map view and/or the annual view by clicking or otherwise selecting a desired year in the outlook view.

For example, as shown in FIG. **47**A, the GUI **300** may be configured to display, in the outlook view, a carbon emissions chart **350** comprised of a plurality of vertical bars **351**, or columns, similar to the carbon emissions chart **250** shown in FIG. **14**A, for example. Each bar **351** may be configured to graphically represent CO2 emissions data for a respective one of the years represented in the chart **350** (e.g., from 2019 to 2050). In addition, each of the bars **351** may be configured to be user-selectable in order to allow the user to view more detailed information about the corresponding year upon hovering over, clicking on, or otherwise selecting the bar **351**. For example, in the illustrated embodiment, user selection of the bar **351** representing the year 2045 causes the

GUI **300** to switch from the outlook view shown in FIG. **47**A to the annual view shown in FIG. **47**B, which displays CO2 emissions data for the year 2045, as well as other related information.

FIG. **48** illustrates an exemplary computing device **400** that may be used to carry out one or more aspects of the techniques described herein. In some cases, the computing device **400** can be configured to perform a variety of functions or acts, such as those described in this disclosure (and shown in the accompanying drawings), including generating, displaying, or otherwise providing one or more graphical user interfaces to the user, using the techniques provided herein. For example, the computing device **400** may be used to implement a client device of the user that is configured to generate and/or display the graphical user interfaces described herein. In some cases, the computing device **400** may be used to communicate with a remote server (not shown) or other device that provides backend services for supporting one or more aspects of the techniques described herein. In some cases, the computing device **400** may be used to implement the remote server or other backend device that is in communication with a client device of a user. In some cases, one or more computing devices like computing device **400** may be combined to form a networked system (e.g., a client device in communication with a remote server over a network) that may be used to implement various embodiments.

The computing device **400** may be any type of electronic device capable of displaying the graphical user interfaces described herein and, as needed, interfacing with a network and/or remote server, including, for example, a mobile communication device (e.g., a smart phone or portable telephone) or any other type of mobile computing device (e.g., a tablet or PDA), and a personal computer (e.g., laptop or desktop). It should be appreciated that FIG. **48** is only exemplary and therefore, may be modified as needed, and is not intended to assert or imply any limitation with respect to the environments in which different embodiments may be implemented. In addition, FIG. **48** may include other components than what is shown, or fewer components, as will be appreciated.

The computing device **400** can include various components, including for example, one or more processors **402**, memory **404**, display unit **406**, communications unit **408**, and input/output (I/O) unit **410**, all communicatively coupled by an I/O interface **412**, which may include a system bus, network, or other connection mechanism. It should be understood that examples disclosed herein may refer to computing devices and/or systems having components that may or may not be physically located in proximity to each other. Certain embodiments may take the form of cloud based systems or devices, and the term "computing device" should be understood to include distributed systems and devices (such as those based on the cloud), as well as software, firmware, and other components configured to carry out one or more of the functions described herein. Further, one or more features of the computing device **400** may be physically remote and may be communicatively coupled to the computing device **400**, via the communications unit **408**, for example.

Processor **402** can be configured to execute software instructions stored in memory **404** and control operation of the computing device **400**. Processor **402** may include a general purpose processor (e.g., data processor) and/or a special purpose processor (e.g., graphics processor or digital signal processor (DSP)). Processor **402** may be any suitable processing device or set of processing devices for processing, inputting, outputting, manipulating, storing, or retrieving data, such as, but not limited to, a central processing unit, a microprocessor, a microcontroller-based platform, an integrated circuit, one or more field programmable gate arrays (FPGAs), and/or one or more application-specific integrated circuits (ASICs).

Memory **404** may be any type of hardware that is capable of storing information on a temporary or permanent basis. Memory **404** may include one or more of a data storage device, an electronic memory, a nonvolatile random access memory (e.g., RAM), flip-flops, a non-transitory computer-writable or computer-readable storage medium or media, a magnetic or optical data storage device, or other electronic device for storing, retrieving, reading, or writing data. In some cases, memory **404** includes multiple kinds of memory, particularly volatile memory and non-volatile memory.

Memory **404** can store one or more computer program modules, computer executable instructions, or other software, such as, e.g., one or more software applications **414** as shown in FIG. **48**, for execution by processor **402**. In embodiments, memory **404** is configured to store one or more sets of instructions or software that, when executed by processor **402**, cause the processor **402** to implement one or more techniques of the present disclosure. For example, the instructions may embody one or more of the methods or other operations described herein for providing the dynamic aviation emissions modeling tool described herein, or otherwise presenting aviation emissions information in a dynamic and interactive manner (such as, e.g., method **500** shown in FIG. **49**). In some cases, the instructions may reside completely, or at least partially, within any one or more of memory **404**, separate computer readable medium, and/or within the processor **402** during execution of the instructions.

In embodiments, the one or more software applications **414** may include a dynamic aviation emissions modeling application configured to implement the methods or operations described herein, such as, for example, the method **500** of FIG. **49**. In some embodiments, the dynamic emissions modeling application may reside on multiple devices, such as, e.g., a client device and a remote server (not shown). The one or more software applications **414** may also include one or more software interfaces or computer programs tailored to interact and exchange data with one or more other components (e.g., a remote server), or with the dynamic aviation emissions modeling application, such as, e.g., a mobile application that can be executed on a smart phone, tablet, or other mobile device, or a web application that can be executed on a desktop computer or laptop.

Communications unit **408** allows the computing device **400** to communicate with one or more devices (or systems) according to one or more protocols. For example, communications unit **408** may comprise one or more radio transceivers configured for communicating with a cellular network, a wireless local area network, a wide area network, a Bluetooth® network, and/or other personal area networks (e.g., RFID, NFC, etc.). Though not shown, communications unit **408** may further include antennas, modems, and other wireless communication circuitry for carrying out wireless communications.

Display unit **406** can be configured to display a visual output on the computing device **400**. The visual output may include, for example, the aviation strategies graphical user interface described herein, other graphical user interfaces described herein, and/or other information (e.g., text, icons, objects, video, or any combination thereof). Display unit

406 may include LCD (liquid crystal display) technology, LPD (light emitting polymer display) technology, LED (light emitting diode) technology, or other display technologies. Display unit **406** may be integrated into the computing device **400** or functionally coupled to the device **400** using a wired or wireless connection, as will be appreciated. In some embodiments, the display unit **406** may be used to implement the display screen **10** shown in various other figures.

I/O unit **410** can be configured to facilitate interaction between a user and the computing device **400**, as well as allow for input and output of data with other devices connected to the computing device **400**. I/O unit **410** may include input components, such as, for example, a keyboard, a keypad, a mouse, a microphone, and a video capture device or camera, and output components, such as, for example, a haptic feedback system and an audio output system or speaker. Some components of the I/O unit **410** may be internal to, or included in, the computing device **400**, while others may be externally located and connected to the computing device **400** using a wireless connection or a wired connection (e.g., Universal Serial Bus ("USB") cable or the like). In some cases, the I/O unit **410** further includes a data port (such as, e.g., a USB port, a mini-USB port, a Lightening connector port, etc.) for receiving data from and/or transmitting data to an external data source or other device coupled to the data port. In some embodiments, the I/O unit **410** further includes a touch sensitive surface disposed over, or on top of, at least a portion of the display unit **406** to collectively form a touchscreen, or touch-sensitive display system. In such cases, the display unit **406** may operate as an output interface between the user and the computing device **400**, while the touch-sensitive surface may operate as an input interface between the user and the computing device **400**.

FIG. **49** illustrates an example process or method **500** for graphically displaying sustainability strategies for an aviation industry, in accordance with embodiments. The method **500** can be carried out by a computing device, alone or in combination with one or more other computing devices, such as, e.g., computing device **400** shown in FIG. **48**. The functionalities of the method **500** can be implemented, at least in part, by a processor of the computing device (e.g., processor **402** shown in FIG. **48**) executing a software application stored in a memory (e.g., memory **404** shown in FIG. **48**). In embodiments, the software application may be the dynamic aviation emissions modeling application, or a portion thereof, as described with reference FIG. **48**. In some embodiments, the application may be a computer program stored on a non-transitory computer readable medium that is executable by a processor of the device.

To further carry out the operations of method **500**, the computing device can interact or interface with one or more external devices communicatively coupled thereto, such as, for example, a remote server (not shown), as well as employ one or more internal devices, such as, e.g., a display unit (e.g., display unit **406** shown in FIG. **48**). For example, upon carrying out the method **500**, the processor can cause the display screen to display one or more graphical user interfaces, including the aviation strategies graphical user interface (e.g., one or more of the graphical user interfaces shown in FIGS. **1** through **47**C). As another example, the data associated with, or presented by, the graphical user interfaces can be retrieved from the remote server and/or one or more databases (not shown).

The method **500** can begin at step **502** with receiving aviation emissions information for a plurality of flights and a select period of time. The information may be received at a computing device from a remote server, database, or other backend service in communication with the computing device, a memory of the computing device, or any other component. The aviation emissions information can comprise measured aviation emissions information collected for a past portion of the select time period and forecasted aviation emissions information determined based on projections for a future portion of the select time period. The select period of time may be user-selected, for example, using slider **151** shown in FIG. **10**. The plurality of flights may also be user-selected or configured, for example, using one or more filters **110** as shown in FIG. **1**. In some embodiments, the method **500** further comprises graphically presenting the plurality of flights on a geographic map user interface included in the aviation strategies graphical user interface (such as, e.g., flights **102** shown in GUI **100** of FIG. **1**).

At step **504**, the method **500** includes displaying, on a display device (e.g., display screen **10**, or display unit **406** of FIG. **48**), an aviation strategies graphical user interface (such as, e.g., GUI **200** in FIG. **22**A). At step **506**, the method **500** includes graphically presenting, via the aviation strategies graphical user interface, the aviation emissions information in association with a plurality of sustainability strategies (such as, e.g., strategy graphics **126** shown in FIG. **7**). In some embodiments, step **506** comprises graphically presenting the aviation emissions information forecasted for a future portion of the select time period using a carbon emissions outlook user interface included in the aviation strategies graphical user interface (such as, e.g., carbon emission outlook graph **150** shown in FIG. **10**). In some embodiments, step **506** comprises assigning a different color to each of the plurality of sustainability strategies, and presenting the aviation emissions information associated with each sustainability strategy in the assigned color (e.g., as shown in FIGS. **34**A and **34**B).

At step **508**, the method **500** includes receiving, via one or more input devices of the aviation strategies graphical user interface, a user input for adjusting a select strategy of the plurality of sustainability strategies. As shown and described herein, the one or more input devices may include user-selectable graphical elements such as, e.g., sliders, toggle buttons, drop down menus, and more.

At step **510**, the method **500** includes based on the user input, dynamically adjusting the graphical presentation of one or more aspects of the aviation emissions information in the aviation strategies graphical user interface (e.g., as shown in FIGS. **36**A to **36**E). In some embodiments, step **510** comprises adjusting a dimension of one or more graphical elements configured to visually represent the one or more aspects of the aviation emissions information (such as, e.g., the bars **128***a*-**128***e* of the bar chart **128** shown in FIG. **9**A). In some embodiments, step **510** comprises adjusting, based on the user input, a first graphical element configured to visually represent the select strategy of the sustainability strategies, and in response to adjustment of the select strategy, automatically adjusting one or more other graphical elements configured to visually represent one or more other strategies of the sustainability strategies, the one or more other strategies configured to be dependent on the select strategy, thus demonstrating a dependency between two different strategies (e.g., as shown in FIG. **9**A and described herein).

Thus, a dynamic display tool is described herein for enabling a user to define various scenarios for reducing CO2 emissions through introduction of one or more sustainability strategies, analyze the impact of those scenarios on emissions, and understand the dependencies between select strategies.

The figures shown herein are based on screenshots taking on a computing device while operating in "light mode." It should be appreciated that the same screenshots could be generated in "dark mode," for example, as shown in FIGS. **35**B and **35**C. In some embodiments, for example, as shown in FIGS. **35**A and **35**B, the GUI **300** may include user-selectable options **390***a* and **390***b* for toggling between the light mode shown in FIG. **35**A and the dark mode shown in FIG. **35**B.

It should be appreciated that the figures include a solid line around the periphery of each screenshot in order to represent an exemplary display screen **10** on which the corresponding graphical user interface may be displayed.

All or portions of the processes described herein, including method **500** of FIG. **49**, may be performed by one or more processing devices or processors (e.g., analog to digital converters, encryption chips, etc.) that are within or external to the computing device **400** of FIG. **48**. In addition, one or more other types of components (e.g., memory, input and/or output devices, transmitters, receivers, buffers, drivers, discrete components, logic circuits, etc.) may also be used in conjunction with the processors and/or other processing components to perform any, some, or all of the steps of the method **500**. As an example, in some embodiments, each of the methods described herein may be carried out by a processor executing software stored in a memory. The software may include, for example, program code or computer program modules comprising software instructions executable by the processor. In some embodiments, the program code may be a computer program stored on a non-transitory computer readable medium that is executable by a processor of the relevant device.

In general, a computer program product in accordance with embodiments described herein includes a computer usable storage medium (e.g., standard random access memory (RAM), an optical disc, a universal serial bus (USB) drive, or the like) having computer-readable program code embodied therein, wherein the computer-readable program code is adapted to be executed by a processor (e.g., working in connection with an operating system) to implement the methods described herein. In this regard, the program code may be implemented in any desired language, and may be implemented as machine code, assembly code, byte code, interpretable source code or the like (e.g., via C, C++, Java, ActionScript, Python, Objective-C, JavaScript, CSS, XML, and/or others). In some embodiments, the program code may be a computer program stored on a non-transitory computer readable medium that is executable by a processor of the relevant device.

The terms "non-transitory computer-readable medium" and "computer-readable medium" include a single medium or multiple media, such as a centralized or distributed database, and/or associated caches and servers that store one or more sets of instructions. Further, the terms "non-transitory computer-readable medium" and "computer-readable medium" include any tangible medium that is capable of storing, encoding, or carrying a set of instructions for execution by a processor or that cause a system to perform any one or more of the methods or operations disclosed herein. As used herein, the term "computer readable medium" is expressly defined to include any type of computer readable storage device and/or storage disk and to exclude propagating signals.

Any process descriptions or blocks in the figures, such as, e.g., FIG. **49**, should be understood as representing modules, segments, or portions of code that include one or more executable instructions for implementing specific logical functions or steps in the process, and alternate implementations are included within the scope of the embodiments described herein, in which functions may be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those having ordinary skill in the art.

This disclosure is intended to explain how to fashion and use various embodiments in accordance with the technology rather than to limit the true, intended, and fair scope and spirit thereof. The foregoing description is not intended to be exhaustive or to be limited to the precise forms disclosed. Modifications or variations are possible in light of the above teachings. The embodiment(s) were chosen and described to provide the best illustration of the principle of the described technology and its practical application, and to enable one of ordinary skill in the art to utilize the technology in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the embodiments as determined by the appended claims, as may be amended during the pendency of this application for patent, and all equivalents thereof, when interpreted in accordance with the breadth to which they are fairly, legally, and equitably entitled.

What is claimed is:

1. A computer-implemented method of graphically displaying sustainability strategies for an aviation industry, the method comprising:

receiving, at one or more processors, aviation emissions information for a plurality of flights and a select time period;

displaying, on a display device, an aviation strategies graphical user interface;

graphically presenting, via the aviation strategies graphical user interface and using the one or more processors, the aviation emissions information in association with a plurality of sustainability strategies;

receiving, via one or more input devices of the aviation strategies graphical user interface, a user input for adjusting a select strategy of the plurality of sustainability strategies; and

based on the user input, dynamically adjusting, using the one or more processors, the graphical presentation of one or more aspects of the aviation emissions information in the aviation strategies graphical user interface.

2. The method of claim **1**, further comprising: graphically presenting, using the one or more processors, the plurality of flights on a geographic map user interface included in the aviation strategies graphical user interface.

3. The method of claim **1**, wherein graphically presenting the aviation emissions information comprises: graphically presenting the aviation emissions information forecasted for a future portion of the select time period using a carbon emissions outlook user interface included in the aviation strategies graphical user interface.

4. The method of claim **1**, wherein graphically presenting the aviation emissions information comprises: assigning a different color to each of the plurality of sustainability strategies; and presenting the aviation emissions information associated with each sustainability strategy in the assigned color.

5. The method of claim 1, wherein dynamically adjusting graphical presentation comprises: adjusting a dimension of one or more graphical elements configured to visually represent the one or more aspects of the aviation emissions information.

6. The method of claim 1, wherein dynamically adjusting the graphical presentation comprises:

adjusting, based on the user input, a first graphical element configured to visually represent the select strategy of the sustainability strategies; and

in response to adjustment of the select strategy, automatically adjusting one or more other graphical elements configured to visually represent one or more other strategies of the sustainability strategies, the one or more other strategies configured to be dependent on the select strategy.

7. The method of claim 1, wherein the aviation emissions information comprises measured aviation emissions information collected for a past portion of the select time period and forecasted aviation emissions information determined based on projections for a future portion of the select time period.

8. A system comprising:

a display device; and

one or more processors communicatively coupled to the display device, the one or more processors configured to:

receive aviation emissions information for a plurality of flights and a select time period; and

display, via the display device, an aviation strategies graphical user interface,

wherein the aviation strategies graphical user interface is configured to:

graphically present the aviation emissions information in association with a plurality of sustainability strategies;

receive, via one or more input devices of the aviation strategies graphical user interface, a user input for adjusting a select strategy of the plurality of sustainability strategies; and

based on the user input, dynamically adjust the graphical presentation of one or more aspects of the aviation emissions information.

9. The system of claim 8, wherein the aviation strategies graphical user interface comprises a geographic map user interface configured to graphically present the plurality of flights.

10. The system of claim 8, wherein the aviation strategies graphical user interface comprises a carbon emissions outlook user interface configured to graphically present the aviation emissions information predicted forecasted for a future portion of the select time period.

11. The system of claim 8, wherein graphically present the aviation emissions information comprises: assign a different color to each of the plurality of sustainability strategies; and present the aviation emissions information associated with each sustainability strategy in the assigned color.

12. The system of claim 8, wherein dynamically adjust the graphical presentation comprises:

adjust a dimension of one or more graphical elements configured to visually represent the one or more aspects of the aviation emissions information.

13. The system of claim 8, wherein dynamically adjust the graphical presentation comprises:

adjust, based on the user input, a first graphical element configured to visually represent the select strategy of the sustainability strategies; and

in response to adjustment of the select strategy, automatically adjust one or more other graphical elements configured to visually represent one or more other strategies of the sustainability strategies, the one or more other strategies configured to be dependent on the select strategy.

14. The system of claim 8, wherein the aviation emissions information comprises measured aviation emissions information collected for a past portion of the select time period and forecasted aviation emissions information determined based on projections for a future portion of the select time period.

15. A non-transitory computer-readable storage medium comprising instructions that, when executed by one or more processors, cause the one or more processors to:

receive aviation emissions information for a plurality of flights and a select time period;

display, via a display device, an aviation strategies graphical user interface;

graphically present, via the aviation strategies graphical user interface, the aviation emissions information in association with a plurality of sustainability strategies;

receive, via one or more input devices of the aviation strategies graphical user interface, a user input for adjusting a select strategy of the plurality of sustainability strategies; and

based on the user input, dynamically adjust the graphical presentation of one or more aspects of the aviation emissions information in the aviation strategies graphical user interface.

16. The non-transitory computer-readable storage medium of claim 15, wherein the instructions further cause the one or more processors to: graphically present the plurality of flights on a geographic map user interface included in the aviation strategies graphical user interface.

17. The non-transitory computer-readable storage medium of claim 15, wherein graphically present the aviation emissions information comprises: graphically present the aviation emissions information forecasted for a future portion of the select time period using a carbon emissions outlook user interface included in the aviation strategies graphical user interface.

18. The non-transitory computer-readable storage medium of claim 15, wherein graphically present the aviation emissions information comprises: assign a different color to each of the plurality of sustainability strategies; and present the aviation emissions information associated with each sustainability strategy in the assigned color.

19. The non-transitory computer-readable storage medium of claim 15, wherein dynamically adjust the graphical presentation comprises: adjust a dimension of one or more graphical elements configured to visually represent the one or more aspects of the aviation emissions information.

20. The non-transitory computer-readable storage medium of claim 15, wherein dynamically adjust the graphical presentation comprises:

adjust, based on the user input, a first graphical element configured to visually represent the select strategy of the sustainability strategies; and

in response to adjustment of the select strategy, automatically adjust one or more other graphical elements configured to visually represent one or more other strategies of the sustainability strategies, the one or more other strategies configured to be dependent on the select strategy.

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