UNDER2°
Secretariat
CLIMATE GROUP

CLIMATE TRACE

A view from space:

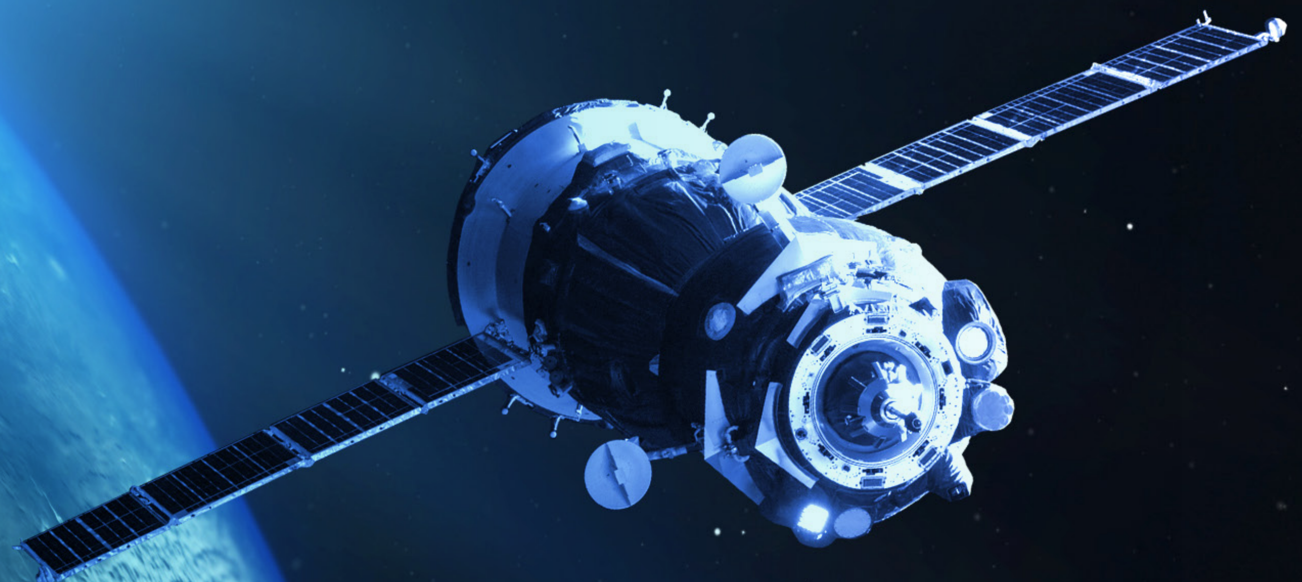
Tracking emissions state by state

STARRS

States And Regions Remote Sensing Project

Executive summary

States and regions are vital players on the path to global net zero emissions, with significant power to drive positive climate impact. However, they're often held back by a lack of timely and granular data, as well as limited time and resources to target effective climate action.



The States and Regions Remote Sensing (STARRS) project, initiated by Climate Group and Climate TRACE, and funded by ClimateWorks Foundation and Google.org, has been working to change this.

The year-long pilot has used satellite and other remote sensing data combined with artificial intelligence (AI) to provide six states and regions around the world with a recent time series of greenhouse gas (GHG) emissions data. The project has successfully generated emissions data for nearly all major emitting sectors of the states' economies.

With improved emissions data, states and regions can track their progress in a timely manner. They can prioritise strategic policies and deliver high-impact emissions reductions in key sectors and locations.

Background

Much attention is paid to national-level pledges. Under the Paris Agreement, national governments have mechanisms for tracking and reporting their progress towards emissions reduction goals. The same doesn't exist for subnational governments. But that doesn't mean their role is any less significant.

States and regions are vital players on the path to global net zero emissions. They have the power to implement sector-wide policies to significantly reduce regional emissions and contribute to national-level emissions reduction targets.

According to research from the NewClimate Institute, if states and regions from the ten countries with the largest annual GHG emissions fully implemented all their existing climate pledges, they could mitigate an additional 16 gigatons CO_2e per year below current national policies' emissions projections for 2030. That's equal to China's GHG emissions for 2021, based on Climate TRACE data. And it would lead to total emission levels close to the range for a 2°C emissions pathway.[1]

However, many subnational governments, especially those in the Global South, lack comprehensive assessments of their GHG emissions. They don't have data. And the main barriers are a lack of time and resources.

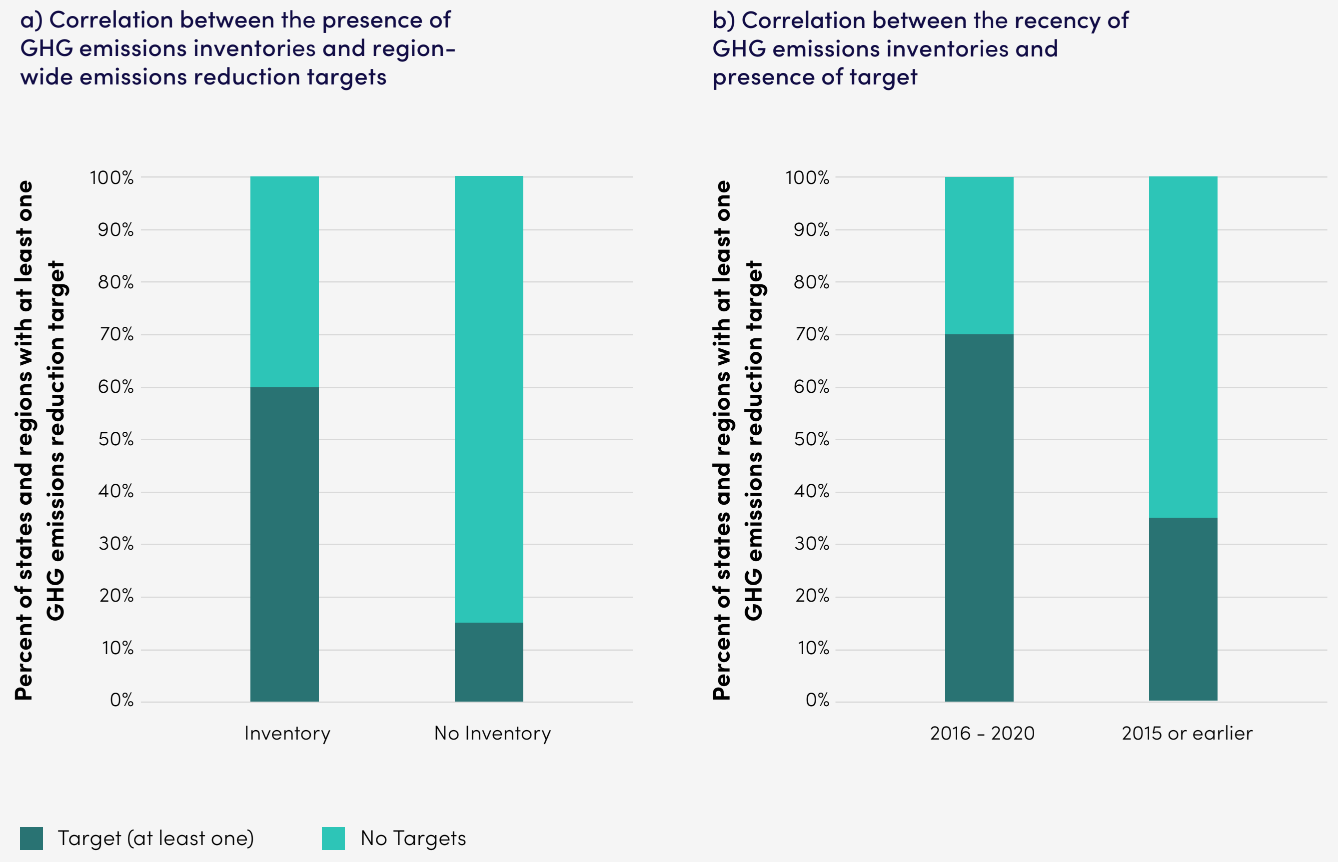
States and regions need granular and timely emissions data so they can plan, implement and track targeted mitigation action. These data are key for setting strategic policies and enabling data-driven decision making to reduce emissions.

Climate Group's research shows that a lack of GHG emissions data correlates with a lack of mitigation targets. 60% of states and regions that reported a verifiable GHG inventory based on data from Climate Group and CDP's *Global States and Regions 2020 Annual Disclosure*[2] also reported at least one region-wide emissions reduction target. Of those without an inventory, only 15% reported setting any region-wide emissions reduction targets at all. In other words, states and regions with emissions inventories are four times more likely to also have emissions reduction targets versus those that lack such inventories.

Figure 1: Shows the correlation between *(a) the presence of GHG emissions inventories and the presence of at least one region-wide emissions reduction target and (b) the recency of state and regional GHG emissions inventories and the presence of at least one emissions reduction target.* Numbers in the bars represent states and regions counted.

Beyond target setting, GHG emissions data are also essential for effective climate action tracking. Having access to a detailed breakdown of region-wide GHG emissions allows states and regions to identify their highest-emitting sectors and activities. It represents a powerful tool to quantify the potential impact of policies and plans — helping states and regions accurately determine the actions and policies that are needed to achieve their targets. Once governments have a baseline inventory to measure against, they can use continuously updated GHG emissions data to track the actual impact of their climate action over time and importantly, revise their strategies accordingly. These inventories can also be included in proposals to access climate finance.

Figure 1



Barriers to region wide GHG emissions accounting

The three main barriers states and regions face when compiling regional GHG emissions data are: **time, resources and technological constraints**. These are repeated challenges that Climate Group and technical partners have heard in discussions with Global South states and regions.

Creating a GHG emissions inventory via a traditional bottom-up approach (e.g., collecting self-reported data from companies and facilities that produce emissions or installing monitoring equipment on emitting facilities) is time intensive. It can take up to two years, or in some cases longer. This approach is also resource intensive. It requires a lot of people from across different departments and organisations, although a standardised process for requesting and accessing data can speed up data compilation.

Given these challenges, state and regional GHG inventories are often outdated, meaning that they no longer provide an accurate reflection of the region's latest emissions trends. In fact, it's not uncommon for developed governments, with extensive GHG emissions accounting processes, to have a lag of one or two years between the time GHG emissions were measured and when the inventory was completed and published.

Timely or not, bottom up GHG inventories come with a high price tag. Whether they're compiled internally or with the support of external contractors, GHG emissions accounting is expensive and time consuming.

Data gaps can also emerge if data are not collected and stored in a consistent and systematic way, particularly for complex sectors such as Agriculture, Forestry, and Other Land Use (AFOLU). Even states and regions with greater-than-average capacity to measure GHG emissions show variations in sector coverage, and completed inventories may only be partial.

Harnessing satellites and artificial intelligence to track GHGs globally

Given these challenges, Climate Group, as Secretariat of the Under2 Coalition, connected states and regions with Climate TRACE (Tracking Real-Time Atmospheric Carbon Emissions).

Climate TRACE is a global nonprofit coalition created to make meaningful climate action faster and easier by providing timely and independent data on GHG emissions. It incorporates different types of satellite imagery (mainly from the visible to infrared spectrum) collected by various space agencies and organisations from around the world. The system uses AI "trained" to spot activity indicators of GHG emissions in the satellite imagery, such as steam plumes from power plant stacks or hot spots in steel plants. These indicators are linked to ground truth data collected from ground- and sea-based physical sensors, government datasets and other sources from data-rich regions. This allows the AI to "learn" and estimate GHG emissions. Once trained, these AI models can be deployed in regions that haven't traditionally had access to data on GHG emissions but have satellite imagery available to identify the indicators of GHG emissions.

Remote sensing technologies, including satellites, can provide a snapshot of emissions-causing activities. Measurements depend on the frequency of satellite visits. So, for any emissions that vary throughout the day, such as power plants, factories and vehicle fleets, Climate TRACE can only produce an estimate rather than a true measured value. Incorporating bottom-up inventories that use direct monitoring helps to fill these gaps. They provide a baseline and account for long-term conditions and variations. In cases where ground truth data are not available, Climate TRACE uses other methods, like comparing with official inventories and non-emissions data (such as production estimates).

Figure 2: *Shows how Climate TRACE member TransitionZero uses multispectral satellite imagery to detect heat-intensive areas, or hotspots, at steel plants to estimate emissions.*

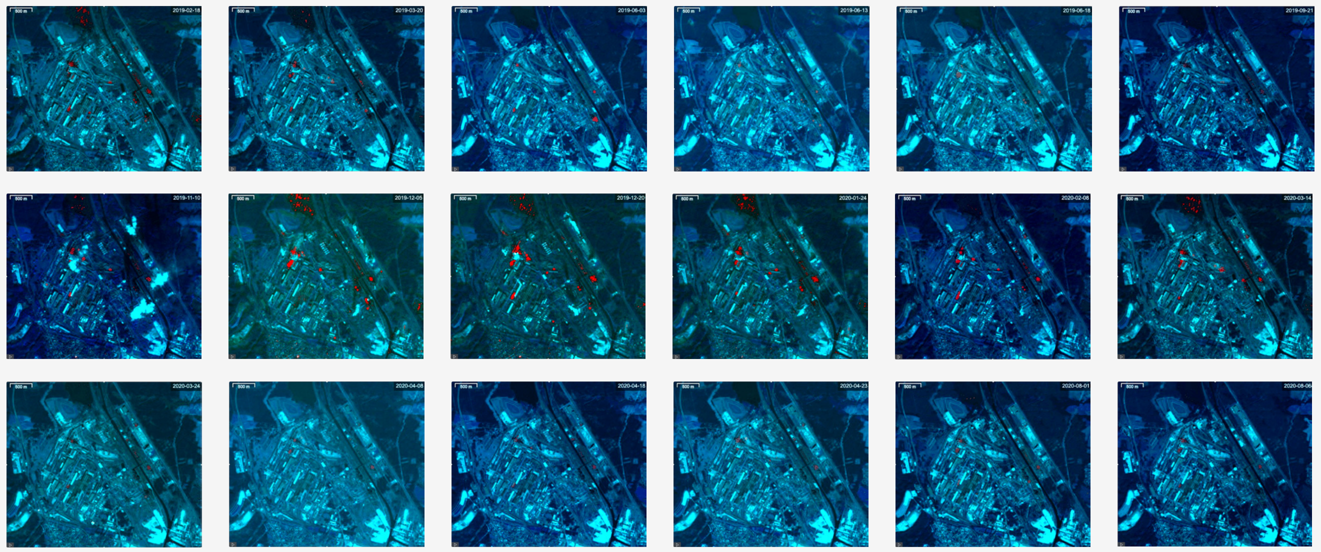
Climate TRACE's global GHG inventory covers annual emissions spanning the years 2015 – 2021 for all major emitting sectors in every country and most territories. In addition to national emissions totals, Climate TRACE's inventory also includes data for more than 70,000 of the largest individual sources of GHG emissions, including individual power plants, ships, refineries and more. Like many AI applications, the project will continuously improve, adding even more sources and improving accuracy as more data and more sophisticated algorithms are incorporated.

Climate TRACE aims to support governments with limited resources and capacity through the wide-scale application of these technologies to emissions monitoring. This will have many benefits for states and regions. They'll be able to dedicate their time and resources to collaborative planning and action – avoiding resource-intensive GHG emissions data collection – and still benefit from a detailed understanding of their jurisdictional emissions.

Figure 2: Harnessing satellites and AI to track emissions

Detecting the heat-intensive units at steel mills using multi-spectral satellite imagery

Modified Sentinel-2 imagery of Eisenhuettenstadt mill



Above: Changes across heat intensive units between 18 February 2019 and 6 August 2020

Source: Google data, Copernicus data, TransitionZero analysis

Background

The STARRS project was a one-year pilot initiated by Climate Group, as Secretariat of the Under2 Coalition, and Climate TRACE, with funding from ClimateWorks Foundation and Google.org

STARRS

States And Regions Remote Sensing Project

The STARRS pilot project

Through the project partnership, Climate TRACE has provided six states and regions with timely, localised information on their emissions. They can use this to design more effective policies and take strategic climate action faster.

The pilot states include:

- Abruzzo (Italy)
- Basque Country (Spain)
- Jalisco (Mexico)
- Querétaro (Mexico)
- Pernambuco (Brazil)
- Western Cape (South Africa)

They were identified based on:

1. their interest and need for timely and granular GHG data.
2. the availability of GHG inventories, even outdated, which could serve as a point of comparison and baseline for Climate TRACE. The inventories were also useful to confirm the presence of certain types of sources within their territories.

The pilot states and regions provided ground truth data for the individual sources of emissions in their regions (such as locations of oil and gas facilities, any available point-source estimates or livestock farm locations, etc). They also received a preliminary list of facilities to confirm that none on the list were shut down or wrongly classified. Although Climate TRACE can generate emissions estimates without these inputs from the states, having access to this information provides additional validation for the final estimates. Estimating emissions from all detectable sources in a given geography allows Climate TRACE to generate emissions estimates for a whole state or region.

Participating states and regions were all strongly engaged throughout the project, electing a core team and focal point at the start. Further stakeholders — including national and municipal governments, research and academic organisations, and UN bodies — were engaged through events at Climate Week NYC and COP27.[3]

Project deliverables

The STARRS project estimated relevant GHG emissions and removals metrics.

These included:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Carbon dioxide equivalent (CO_2e)

These emissions were estimated for the following subsectors:

- Electricity generation
- Heavy industry (steel and cement)
- Oil and gas production and refining
- Road transport (urban areas only)
- Aviation
- Synthetic fertiliser application
- Cropland fires
- Beef and dairy feedlots
- Landfills and dumpsites
- Land use change and emissions and removals from biomass change from forests (including mangroves), wetlands, and shrubland-grassland cover types

In addition, data are:

- disaggregated to the facility or smallest area of land possible, and
- covering historical GHG emissions from 2015 to 2021 in most sectors.

Preliminary emissions inventories for each participating state or region have already been generated, and Climate TRACE is now working with the partners to identify future opportunities. A key aspect of the project's impact is the continued data provision: emissions data will continue to be updated annually, and kept accessible, for all of the involved states and regions going forward, even after project completion.

These data, while serving an important purpose of filling gaps and providing an independent source of verification, should be seen as complementary to states' official inventories and not a replacement of state capacity.

Limitations of the project

Although the use of satellite and AI-based technologies can significantly reduce the time and resource costs of preparing inventories, there are some important limitations to the project:

1. Climate TRACE doesn't yet track all emitting sectors at the province level. Examples of sectors not yet included in Climate TRACE data are: light industries, building emissions and non-cattle livestock emissions. Therefore, there are limitations in comparing total emissions estimates from Climate TRACE to previous inventories. Nevertheless, the recency and granularity of these data provides actionable insights to policymakers.
2. With each subsector, plants or factories that are too small for satellite-based methods to detect haven't been included. However, the largest plants are typically disproportionately more emitting than small plants or farms.

Land use change emissions

2015 was treated as a base year to understand biomass change through time. The values in the maps tell the following:

- **Positive values indicate increased emissions from 2015 to 2021. Meaning, 2021 biomass decreased relative to 2015, which led to increased emissions in 2021.**
- **Negative values indicate decreased emissions from 2015 to 2021. Meaning, 2021 biomass increased relative to 2015, which led to decreased emissions in 2021.**

Land use change emissions data in the GHG inventories of states may not be directly comparable to Climate TRACE data since Climate TRACE is only looking at carbon stock change in live biomass. There are other contributors to emissions such as dead biomass, litter and soils.

We assume all biomass loss as "committed emissions", i.e. carbon leaving the land surface and eventually entering the atmosphere.

Abruzzo, Italy

Abruzzo, Italy

Overview

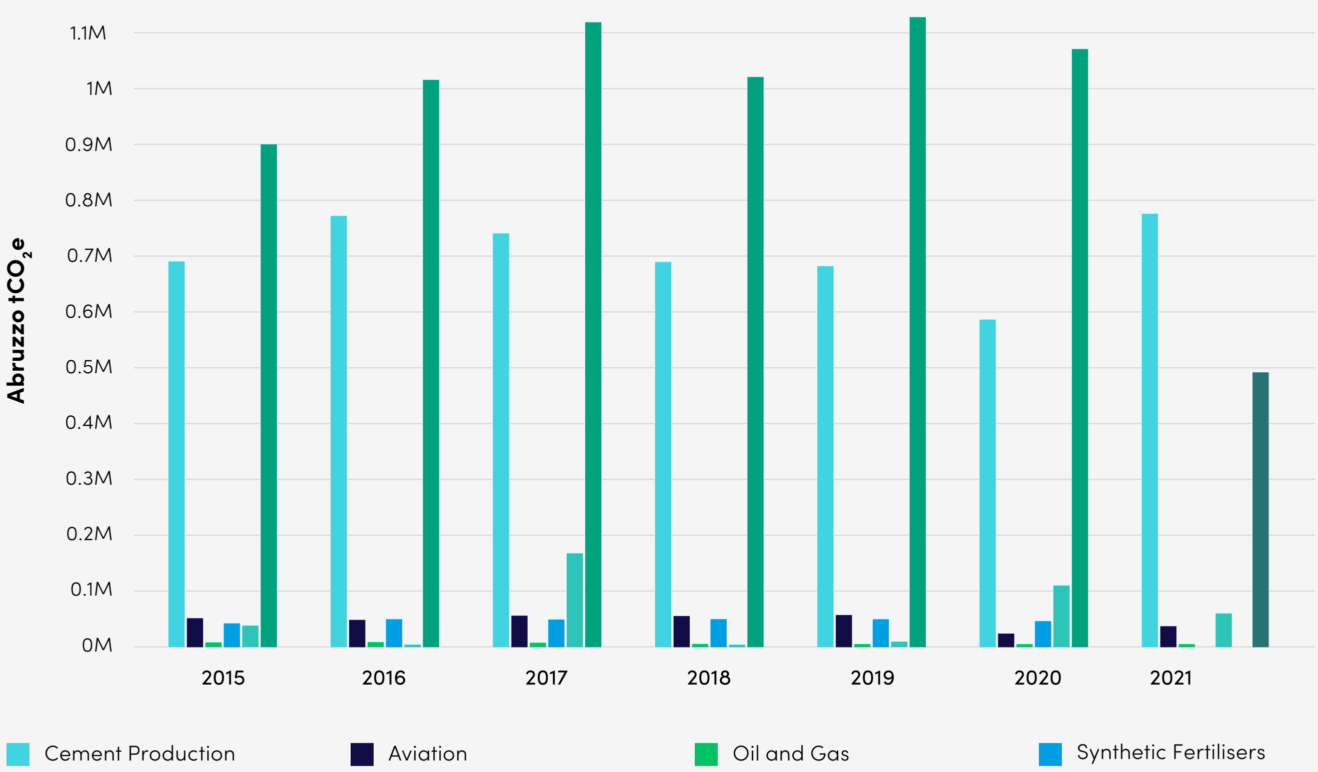
Abruzzo is a region in central Italy to the east-northeast of Rome, stretching from the heart of the Apennine Mountains to the Adriatic Sea. One third of its territory is set aside for national parks and protected nature reserves. Agriculture is one of the main economic activities in the region, alongside industry. Abruzzo has endorsed the European Union's 40% greenhouse gas reduction target by 2030 through the Global Covenant of Mayors for Climate and Energy.[4] As a member of the Under2 Coalition, it's also committed to reaching net zero emissions by no later than 2050. To set mitigation policies and meet its climate goals, the region needs timely emissions data.

Last available inventories

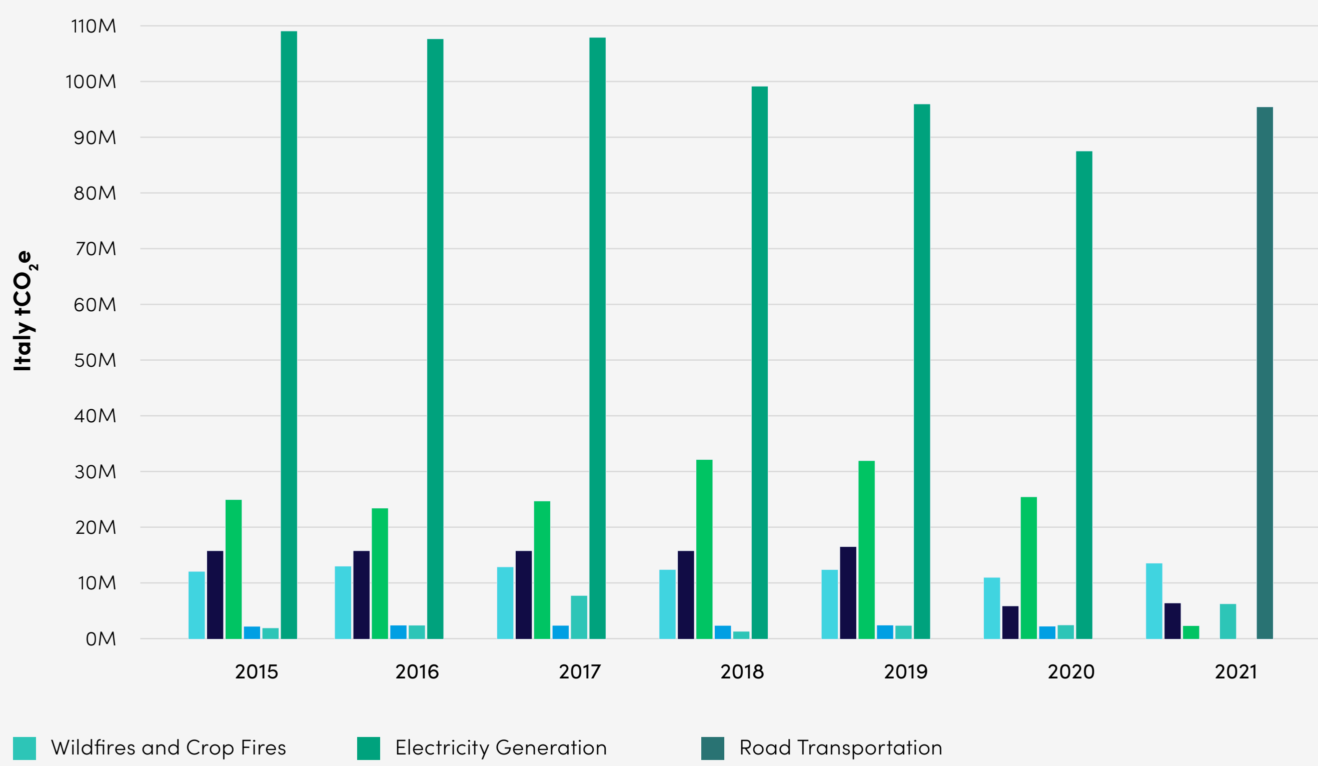
2006, 2010, 2012

Figure 3: Comparing emissions sources at the local and national levels

Abruzzo



Italy



Data Source: Climate TRACE

Why STARRS?

Abruzzo joined the STARRS project with a plan to review and update its regional strategies and programming tools based on the new data, and with the aim to share these data with its key stakeholders. The region also expressed an interest in collecting granular, municipal-level data because of the following challenges:

It's challenging in Abruzzo. We connect with stakeholders, including municipalities, to collect information on emissions, but these data are often inconsistent and incomplete. They come from a wide variety of sources and are incomparable.

We must gather emissions data to understand real needs at the local level. This is crucial to put in place climate strategies and actions that work. We've joined the STARRS project with the hope of finding a better approach to collect consistent data that are easy to understand.

An improved methodology to collect useful information on emissions — meaning verified, comparable and consistent data — is what we need. This will help us to deliver clear and effective medium- and long-term programming at the local and regional levels.

Chiara Barchiesi and Enrico Sevi, Office of EU Direct Management Programmes and Cooperation, Directorate General, Regione Abruzzo

Key findings in Abruzzo's 2021 emissions data

Figure 3: *Shows the sectoral breakdown of emissions in Abruzzo and Italy in 2021.*

Abruzzo's emissions in 2021 are estimated to be 2.4 million metric tonnes CO_2e (excluding the sectors that Climate TRACE does not currently track and excluding land use change). Cement manufacturing, road transportation and electricity generation were the largest emitting subsectors in 2021.

Prior to joining this project, the region relied on a 2012 data inventory. Now, Abruzzo has recent data, and with these, it can develop a more accurate picture of its emissions.

Figure 4: Abruzzo road transport emissions CO_2e in 2021

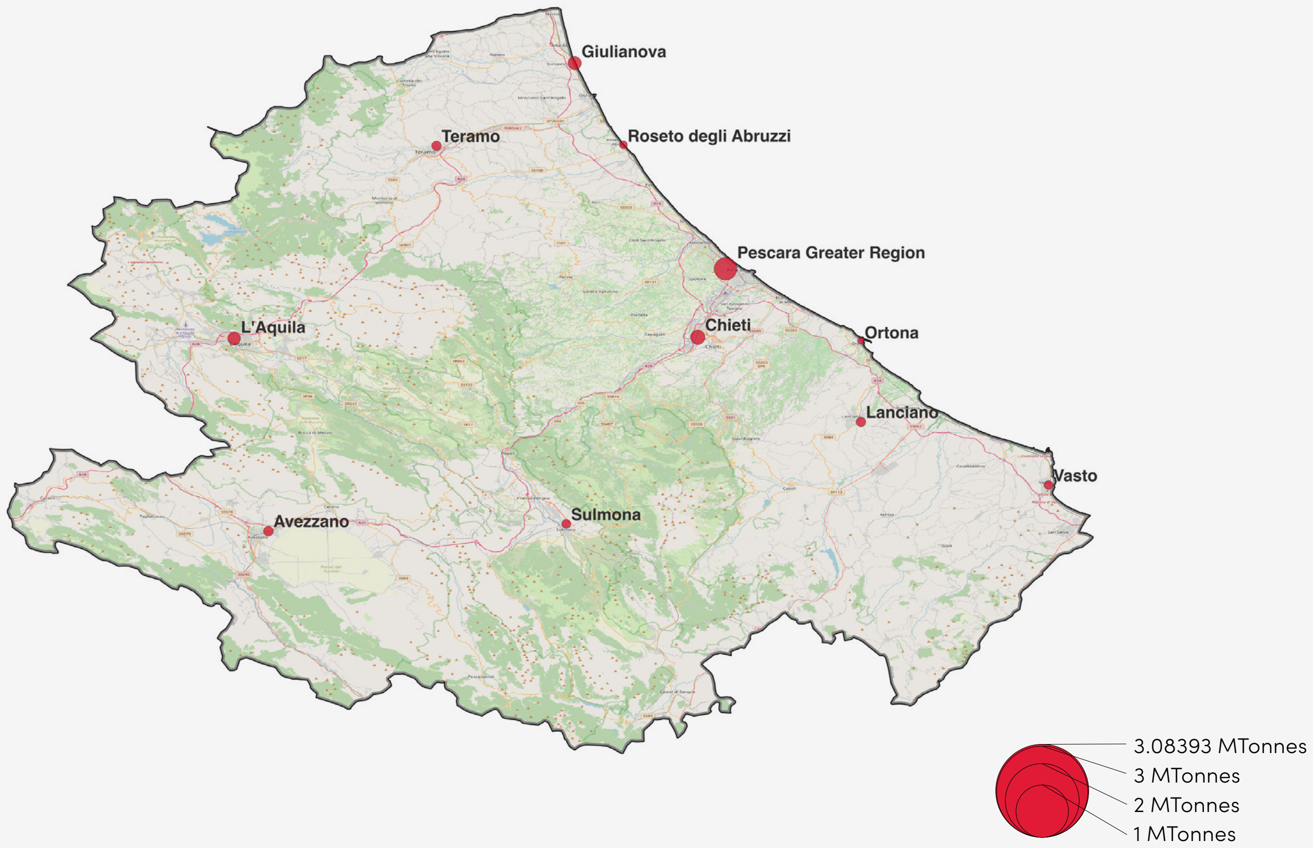
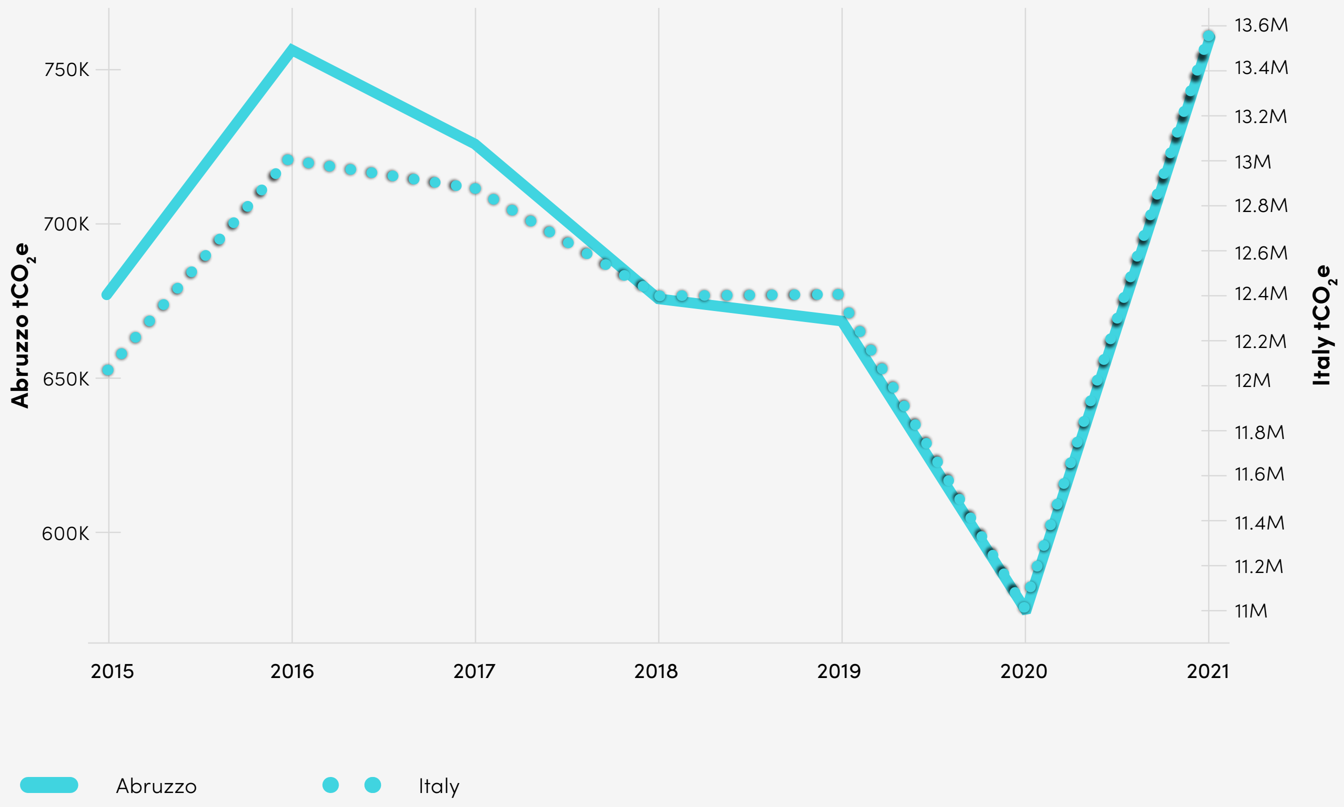


Figure 5: Changes in emissions over time from cement manufacturing



Data Source: TransitionZero

Road transport

As **Figure 3** shows, road transport is one of the biggest contributors to Abruzzo's total emissions — even when considering only transport emissions in urban areas.

The Greater Metropolitan Area of Pescara alone accounts for nearly 40% of total urban road transport emissions in Abruzzo.

This information can help the government prioritise transport policies (such as zero-emissions areas) in the highest-emitting cities in the region.

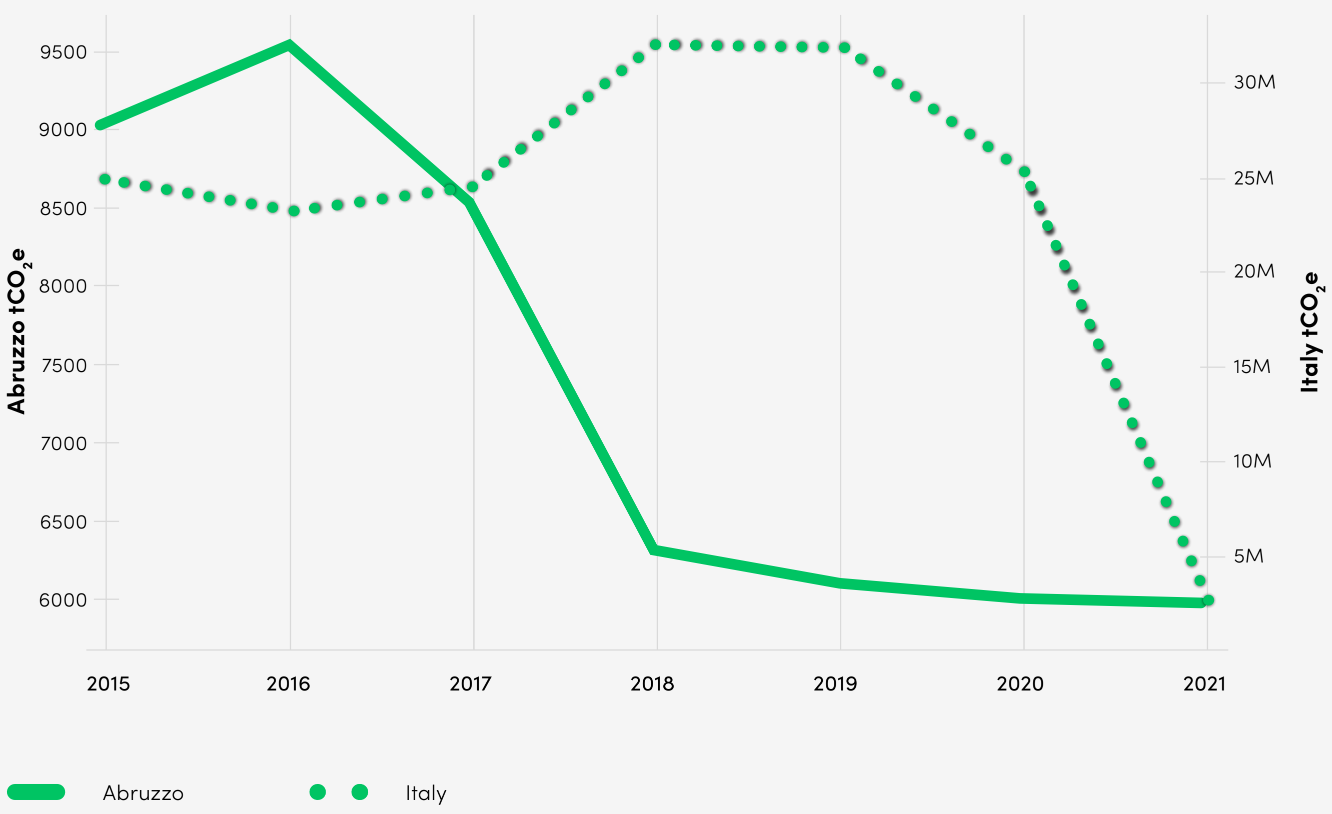
Figure 4: *Shows the emissions from road transport from Abruzzo's cities in 2021*

Cement

Cement manufacturing is also one of Abruzzo's biggest contributors to emissions. Climate TRACE data show that production (and consequent emissions) dropped significantly in 2020 due to COVID-19 but quickly returned to pre-pandemic levels in 2021.

Figure 5: *Shows the change in emissions over time from cement manufacturing in Abruzzo and Italy*

Figure 6: Change in emissions over time from oil and gas production in Abruzzo and Italy



Data Source: RMI

Oil and gas

Oil and gas emissions represent a relatively small percentage of Abruzzo's total 2021 emissions. Historical data show that emissions from this sector have declined significantly since 2016. Although the state has oil reserves offshore, local pushback against oil and gas production led to the closure of a major offshore facility.[5]

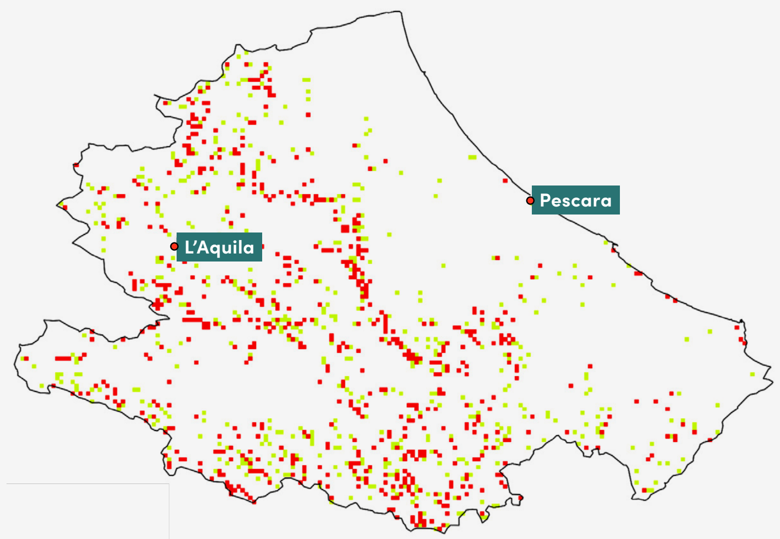
Figure 6: *Shows the change in emissions over time from oil and gas production in Abruzzo and Italy*

Land use change

Forest, wetlands, and shrubland-grassland

Between 2015 and 2021, Abruzzo saw a net gain in live forest and grassland biomass carbon. This means that 2021 biomass increased relative to 2015, which led to decreased emissions in 2021. The increase over this period resulted in ~300,000 tonnes of carbon being sequestered in Abruzzo.

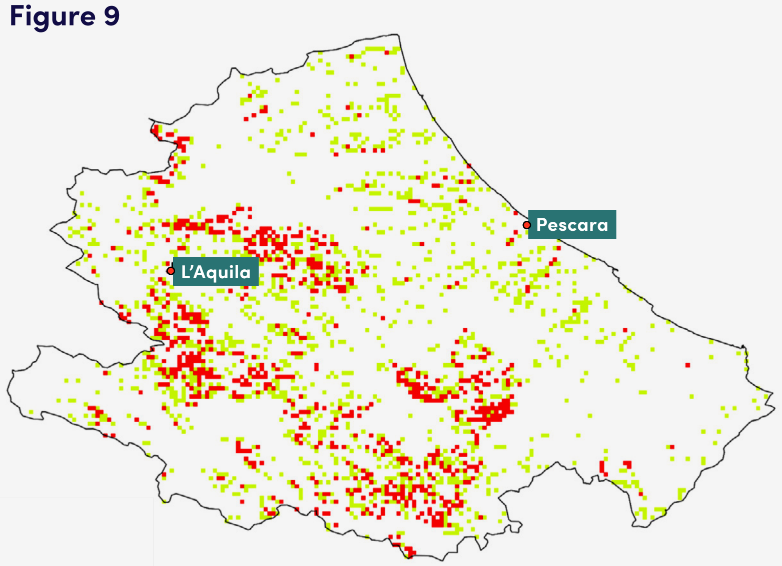
Figure 7



1000 to 1500 | >1500

Figure 7: *Abruzzo forest land biomass loss between 2015 and 2021. Legend value ranges from 1,000 to 1,500 (yellow) and >1,500 (red, largest loss) tonnes of CO_2e.*

Figure 9

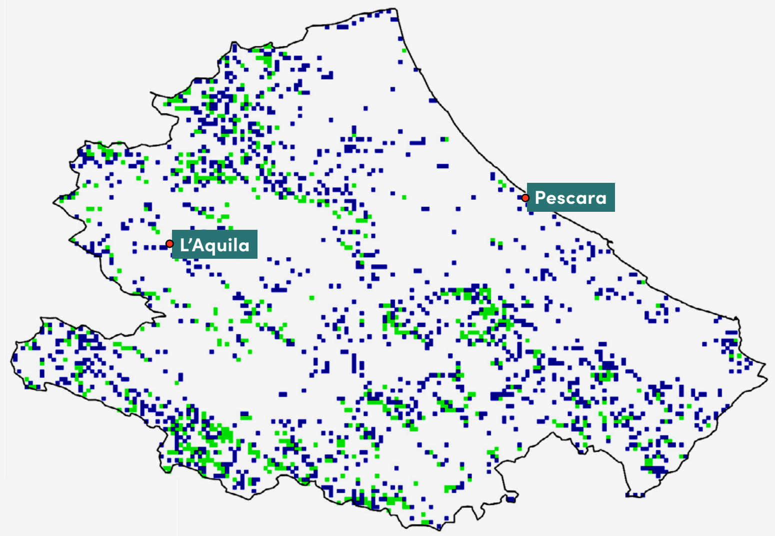


1000 to 1500 | >1500

Figure 9: *Abruzzo shrubland-grassland biomass loss emissions between 2015 and 2021. Legend value ranges from 1,000 to 1,500 (yellow areas) and >1,500 (red areas, largest emission increase) tonnes of CO_2e.*

The below charts show a mixture of biomass loss and gain across forest land biomass and shrubland-grassland biomass. Most regrowth took place in central and western Abruzzo.

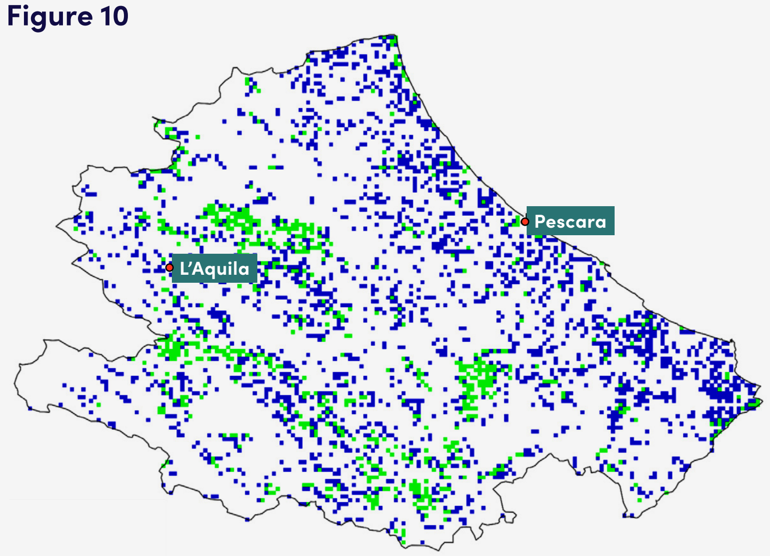
Figure 8



< -2000 | -2000 to -1000

Figure 8: *Abruzzo forest land biomass gain between 2015 and 2021. Legend value ranges from <-2,000 (green, largest increase) and -2,000 to -1,000 (blue) tonnes of CO_2e.*

Figure 10



< -500 | -500 to -100

Figure 10: *Abruzzo shrubland-grassland biomass gain emissions between 2015 and 2021. Legend value ranges from <-500 (green areas, largest emissions decrease) and -500 to -100 (blue areas) tonnes of CO_2e.*

Data Source: CTREES

Basque Country, Spain

Basque Country, Spain

Overview

Basque Country is an autonomous community located in northern Spain. It's a densely populated region of just over 7,000 km² and home to more than two million people.

With a GDP per capita 22% higher than that of the EU, the Basque Country is one of the wealthiest regions in Europe. Its strongest economic sectors include manufacturing, aeronautics, logistics, finance and energy.

The energy, transport and industry sectors are the region's main GHG emitters, accounting for 85% of total emissions.

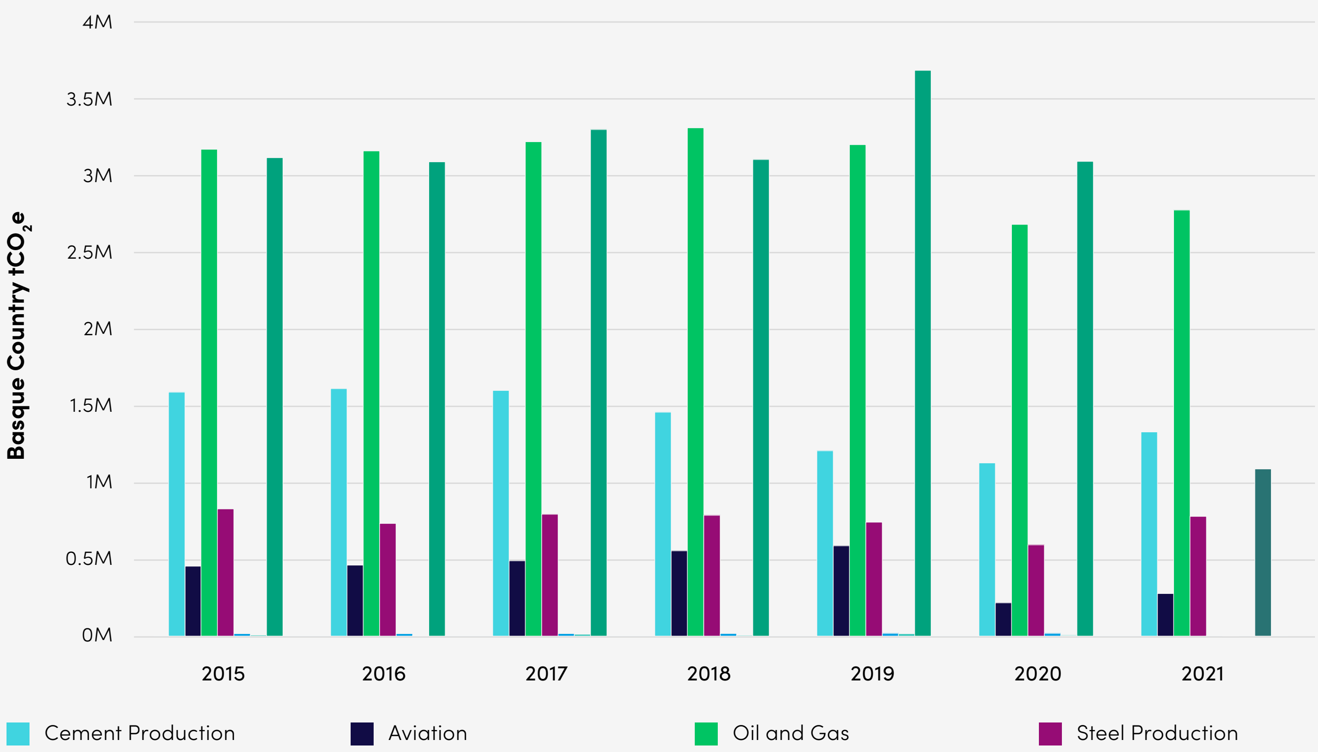
In 2015, the Basque Government published its *Climate Change Strategy 2050*[6], with the target of reducing emissions by 40% in respect to 2005 levels by 2030 and 80% of 2005 levels by 2050. The strategy also sets out to ensure that 40% of the territory's energy is powered with renewable sources.

Last available inventories

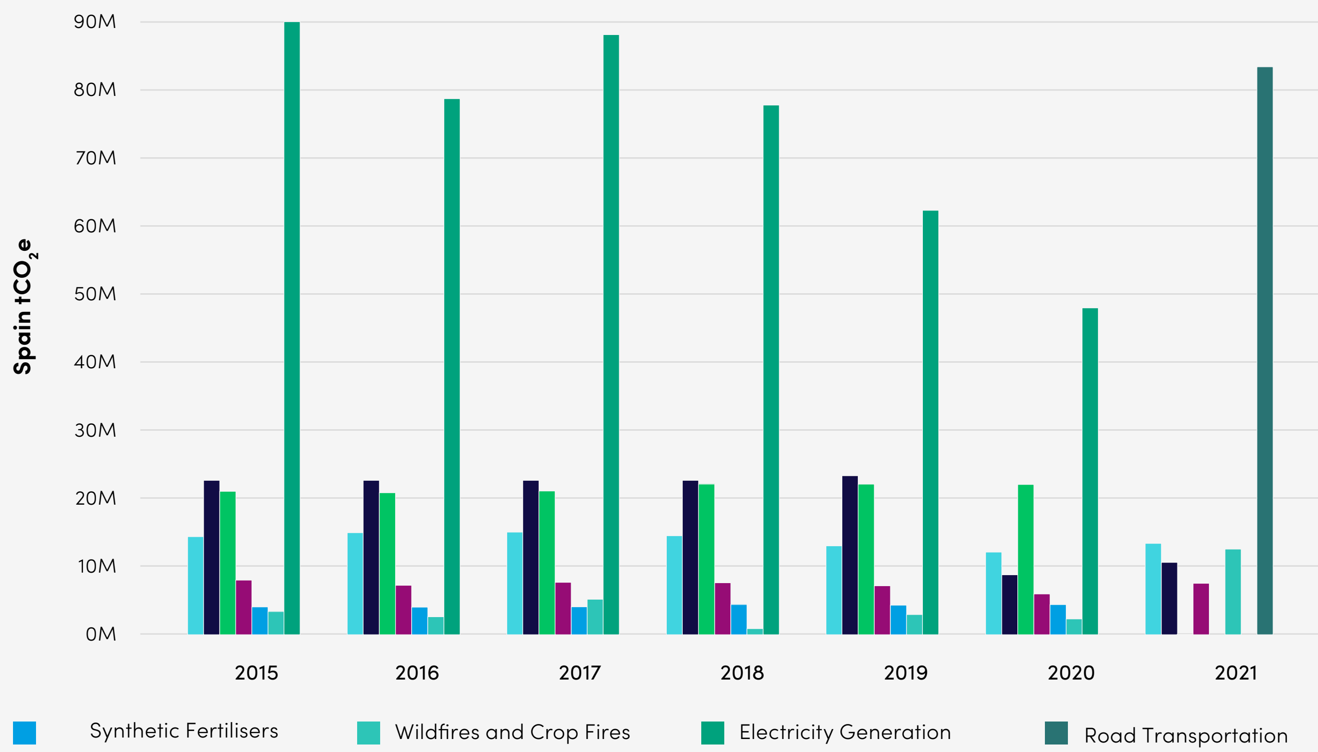
1990–2019

Figure 11: Comparing emissions sources at the local and national levels

Basque Country



Spain



Data Source: Climate TRACE

Why STARRS?

Basque Country updates its emissions inventory annually using bottom-up GHG estimation methods as required by the EU Emissions Trading Scheme (ETS).[7] It joined the STARRS project to calibrate its data, review the pros and cons of alternative methods, and benchmark with other states and regions.

Transparency is key for us to develop good policies. We want to share what we're doing, review our progress against others and take advantage of scientific and technological advances to improve emissions monitoring.

Although in many cases satellite calculations and estimates cannot replace a bottom-up inventory, satellite work has a lot of potential to automate and improve the frequency of data collection. For example, in the Basque Country, satellite data are used to obtain annual data between forest inventories, which are updated every five years.

Whilst satellite data may not help us when using certain proxies, such as national emissions factors, they can be of benefit when we need to measure emissions directly, for example in the case of leaks in natural gas transportation.

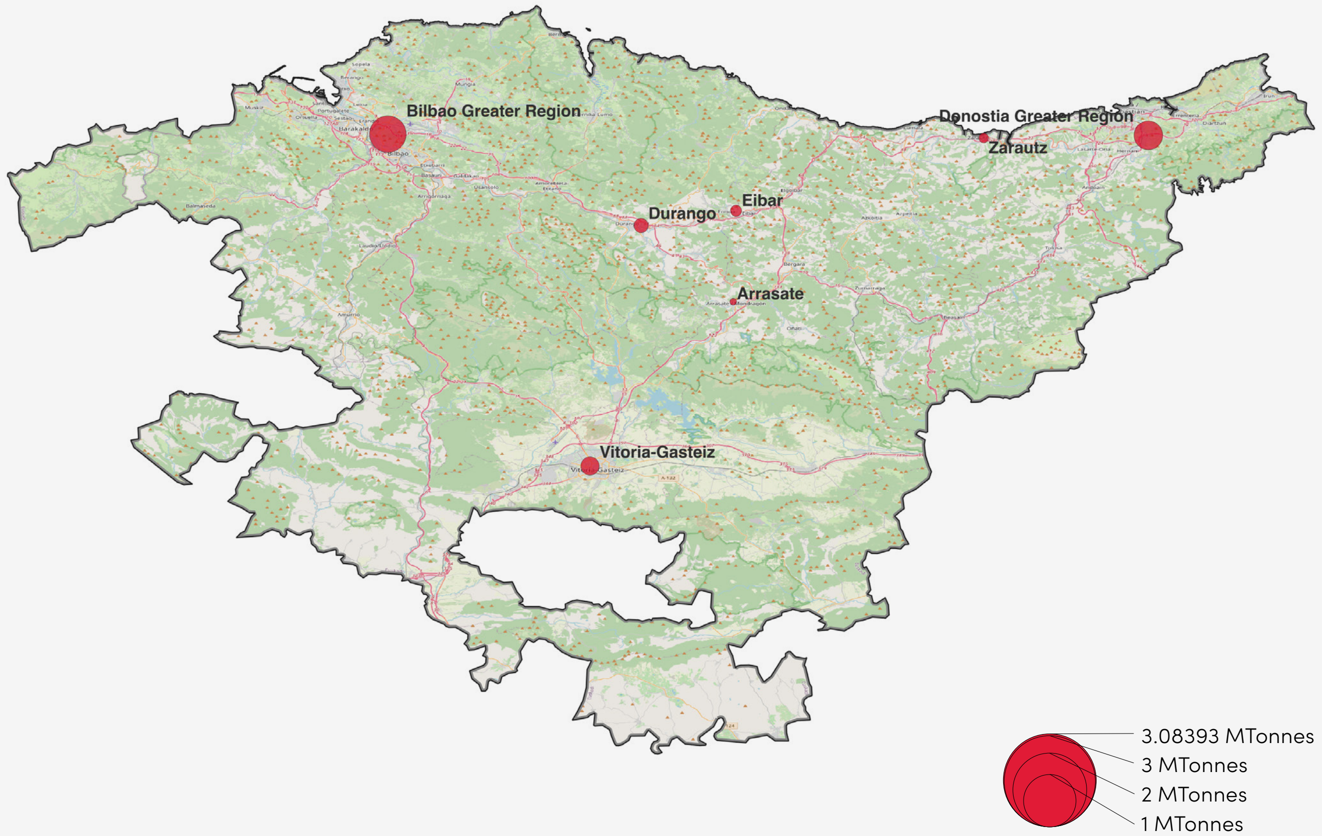
Carlos Castillo, Climate Action Technician, Government of the Basque Country

Key findings in Basque Country's 2021 emissions data

Basque Country's emissions in 2021 are estimated to be 9.1 million metric tonnes CO_2e (excluding the sectors that Climate TRACE does not currently track and excluding land use change). In 2021, cement manufacturing, road transportation, oil refining and electricity were the largest-emitting sectors tracked by Climate TRACE.

Figure 11: *Shows the sectoral breakdown of emissions in the Basque Country and Spain in 2021*

Figure 12: Basque Country road transport emissions CO_2e in 2021



Road transport

Basque Country updates its emissions inventory using the EU ETS. However, this method is based on fuel sales across the entire state and doesn't provide emissions estimates at the city level. By using satellite data, Climate TRACE can estimate transport emissions down to municipalities. This is of huge benefit to states and regions. Measuring emissions based on fuel sales might not be representative of the state's transport emissions. There is no certainty that this fuel is being consumed within the state boundaries, and it doesn't offer any actionable insights on where to target mitigation actions.

Figure 12: *Shows the road transport emissions in Basque Country's cities in 2021*

Figure 13: Emissions over 2015 - 2021 from the Bilbao Refinery in Basque Country

Basque Country

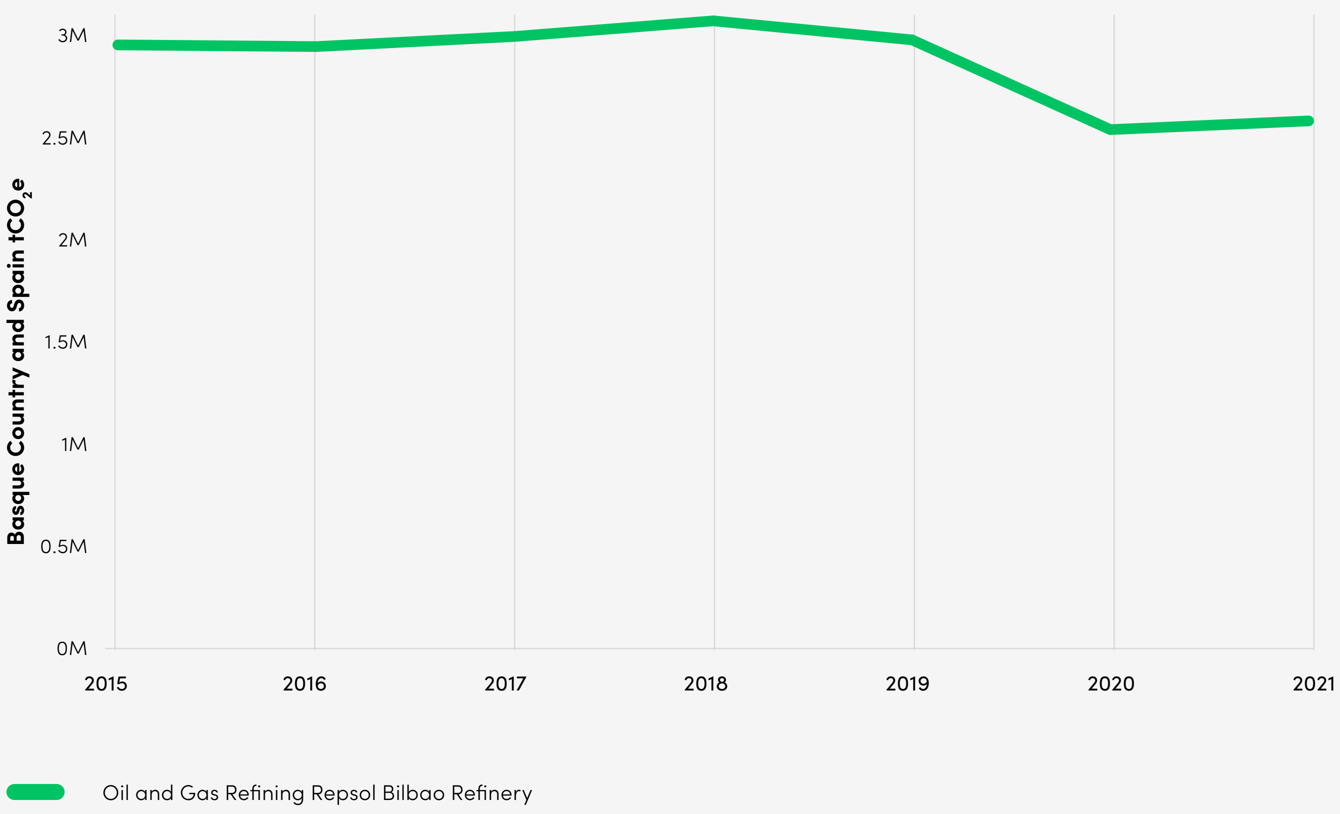


Figure 14: Comparing emissions estimates from ClimateTRACE vs. previous inventories

Spain

Oil and gas refining

Climate TRACE's novel methods for modelling methane have provided up-to-date estimates for the Bilbao Refinery. In 2021, it generated 16% of all oil and gas refining emissions in Basque Country and represented 1% of Spain's total emissions.

These data pointed to a decline in emissions in 2020, likely due to the impact of lockdowns through COVID-19.

Figure 13: *Shows the emissions over 2015 - 2021 from the Bilbao Refinery in Basque Country*

Estimates from Climate TRACE show higher emissions from oil and gas compared to Basque Country's previous inventories.

Figure 14: *Compares emissions estimated from ClimateTRACE versus previous inventories for oil and gas*

Land use change

Forest, wetlands, and shrubland-grassland

Using 2015 as a base year, we found that forest areas, including mangroves, experienced a net biomass loss. This means an increase in emissions. In fact, it resulted in the release of ~6.2 million tonnes of CO_2e between 2015 and 2021. On the other hand, shrubland-grassland areas experienced a net biomass gain. This sequestered ~40,000 tonnes of CO_2e between 2015 and 2021. Most of the forest biomass loss occurred in north-eastern Basque Country, and the shrubland-grassland biomass gain occurred in southcentral and northwest regions.

Figure 15

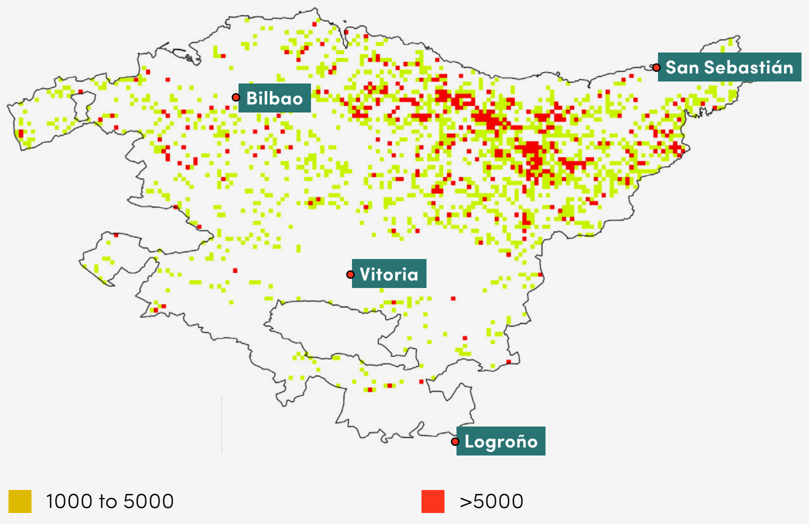


Figure 15: *Basque Country forest land biomass loss between 2015 and 2021. Legend value ranges from 1,000 to 5,000 (yellow) and >5,000 (red, largest emissions increase) tonnes of CO_2e.*

Figure 16

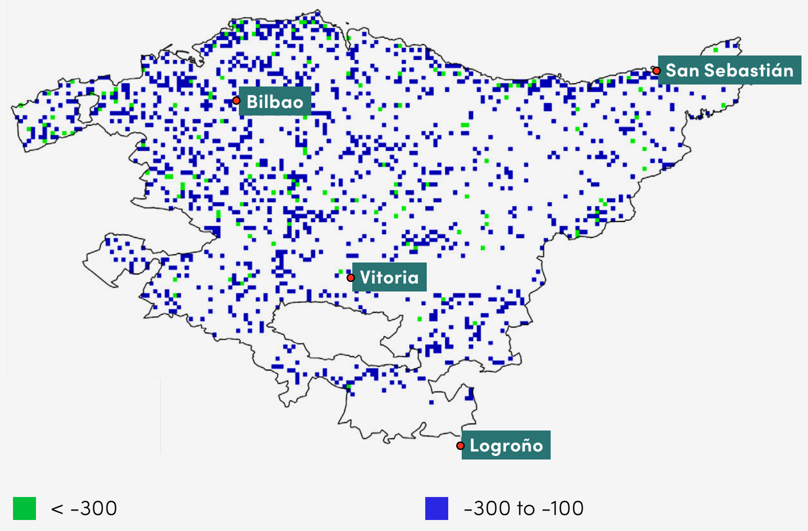


Figure 16: *Basque Country forest land biomass gain between 2015 and 2021. Legend value ranges from <-300 (green, largest emissions decrease) and -300 to -100 (blue) tonnes of CO_2e.*

Figure 17

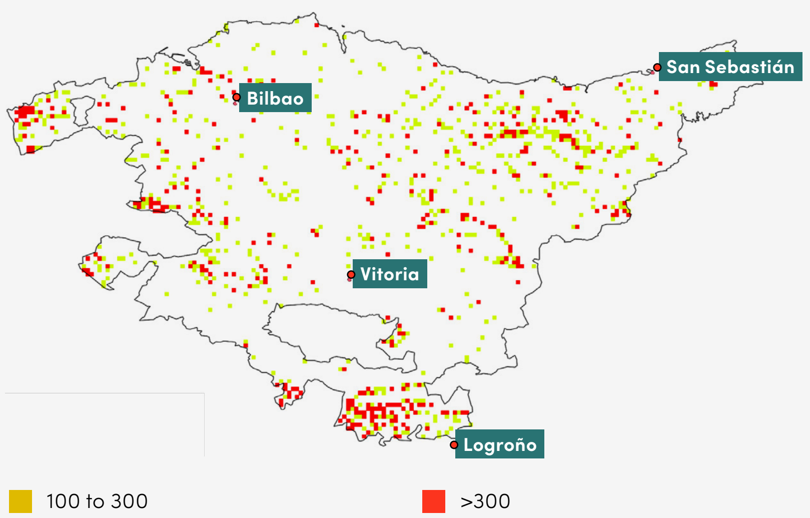


Figure 17: *Basque Country shrubland-grassland biomass loss between 2015 and 2021. Legend value ranges from 100 to 300 (yellow) and >300 (red, largest emissions increase) tonnes of CO_2e.*

Figure 18

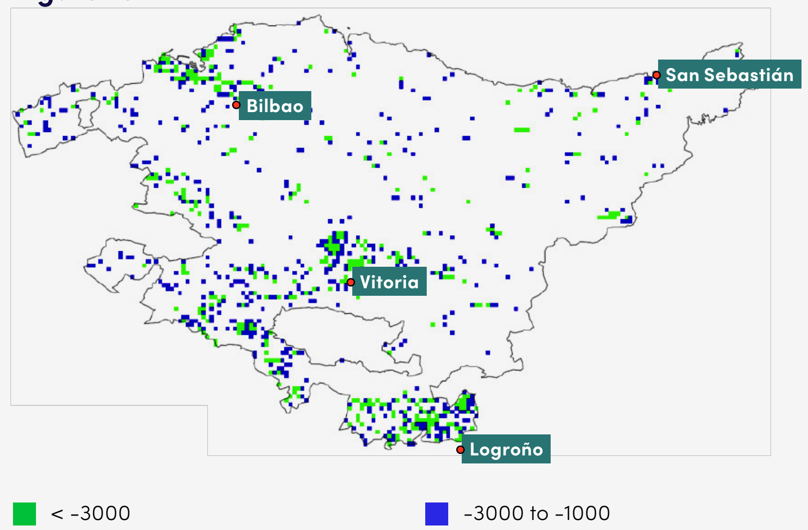
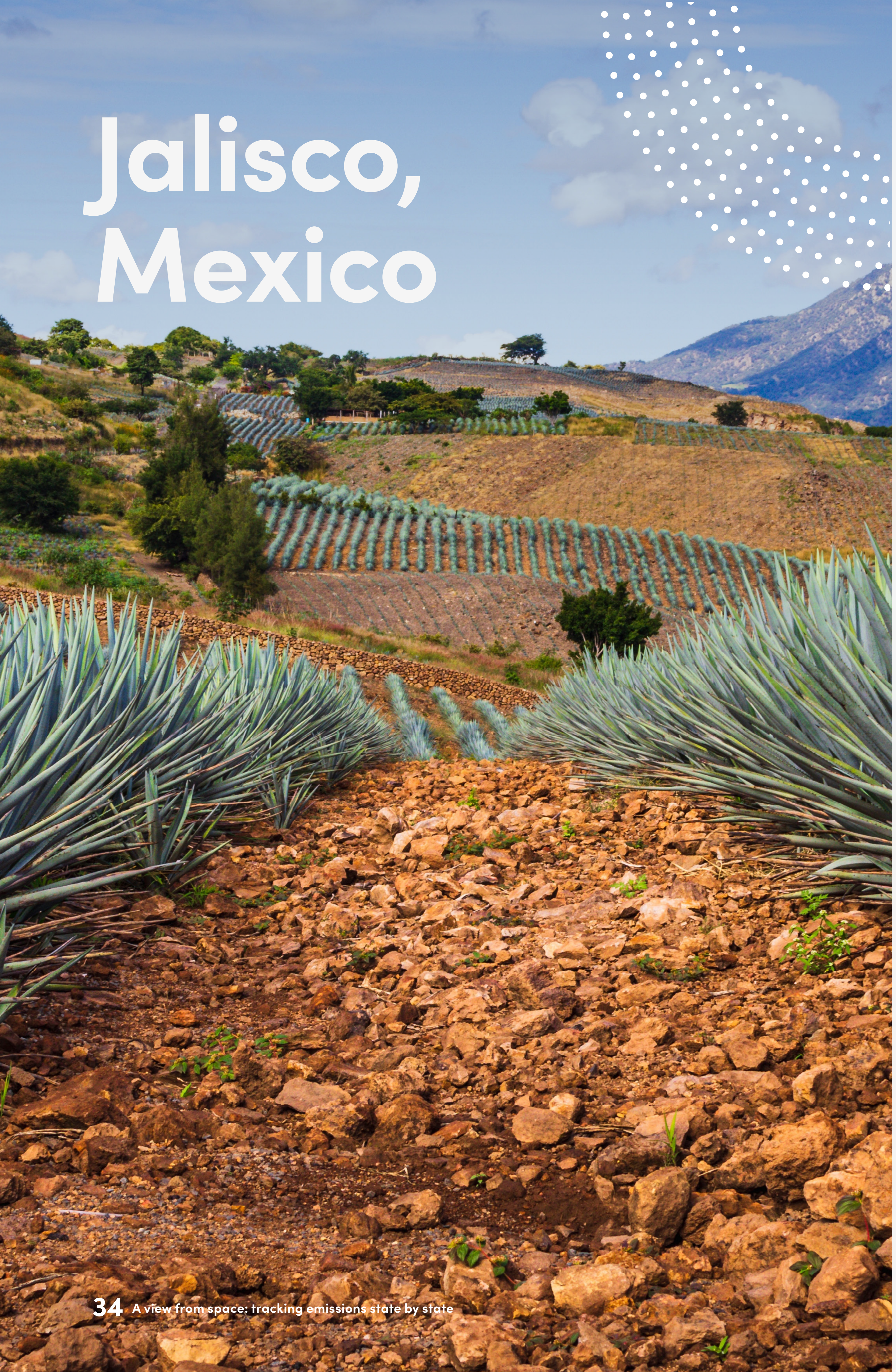


Figure 18: *Basque Country shrubland-grassland biomass gain between 2015 and 2021. Legend value ranges from <-3,000 (green, largest emissions increase) and -3,000 to -1,000 (blue) tonnes of CO_2e.*

Jalisco, Mexico



Jalisco, Mexico

Overview

Jalisco is the seventh largest state in Mexico and comprises 125 municipalities. It's the third most populous state in Mexico, with over eight million residents. About 60% of people live within the greater Guadalajara area, making it the country's third largest city after Mexico City and Monterrey.

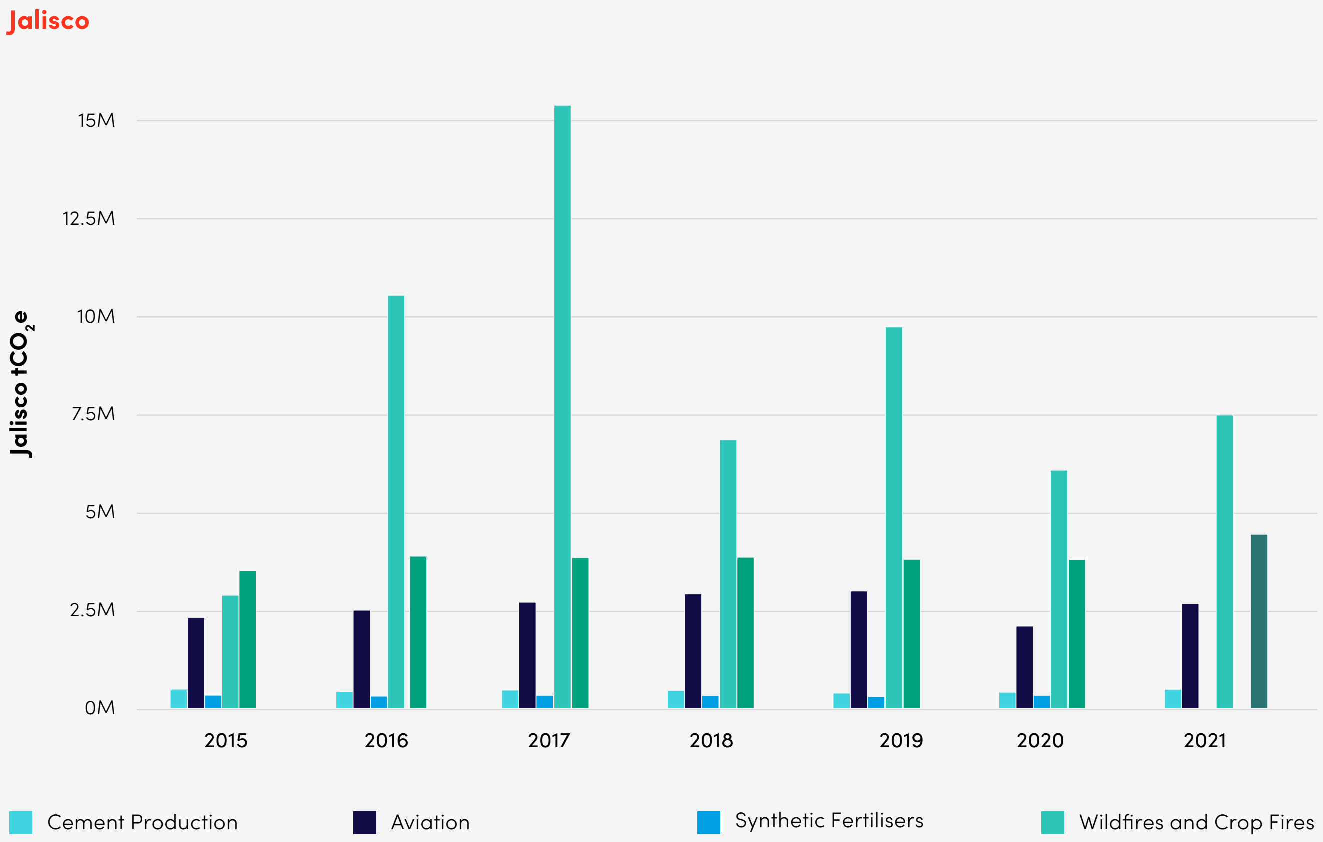
Even though 65% of the state's economic activity comes from the tertiary sector (trade, transport, real estate, and other services), Jalisco is the top national producer of corn, milk, eggs and pork.

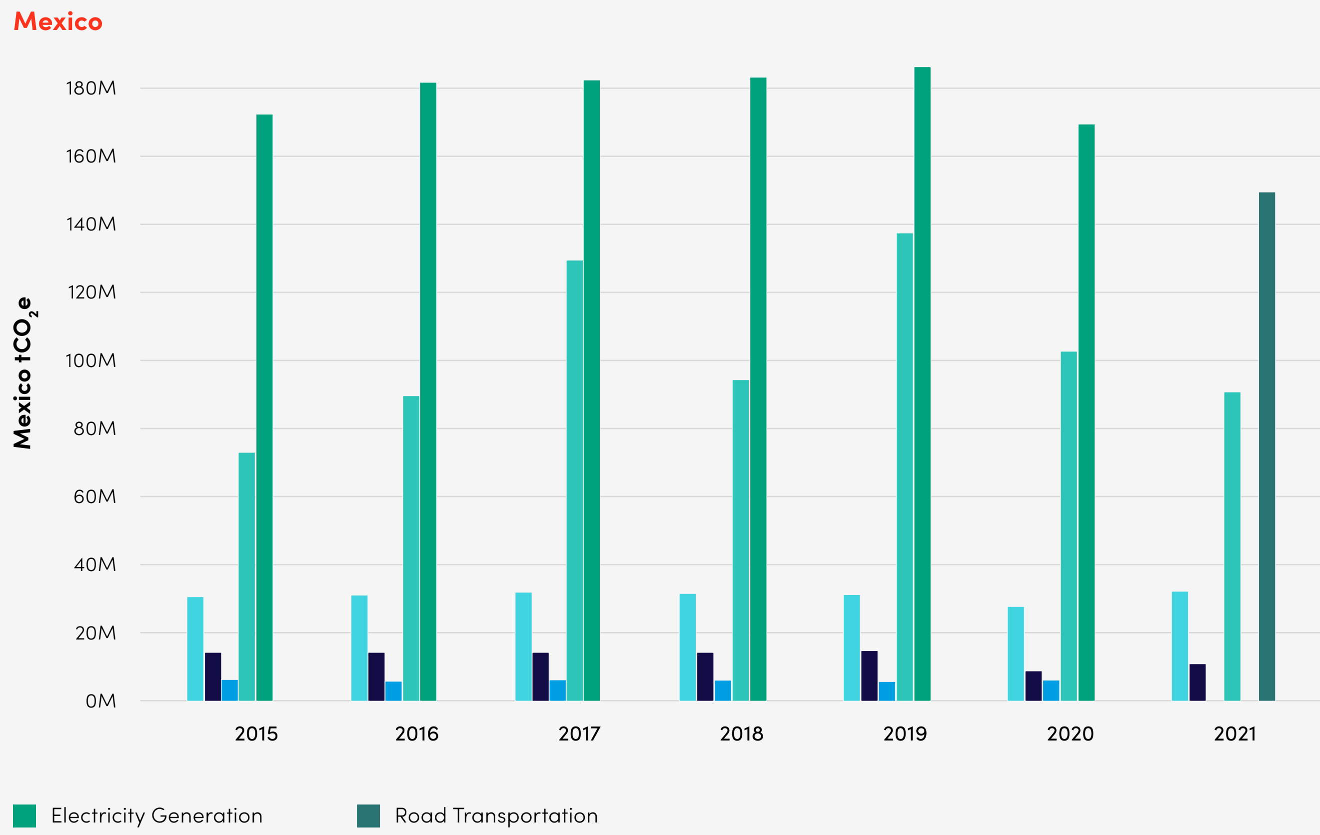
According to its most recent inventory in 2017, most of Jalisco's emissions come from transport (53%), AFOLU (19%) and waste (9%).

Last available inventories

2010–2017

Figure 19: Comparing emissions sources at the local and national levels





Data Source: Climate TRACE

Why STARRS?

In 2018, Jalisco participated in the Under2 Coalition's Climate Footprint Project,[8] which supported states and regions to improve their GHG emissions tracking and reduction efforts. Jalisco joined the STARRS project as a continuation of this work and to build on learnings.

This methodology has opened up new possibilities for considering other assumptions and criteria around emissions data.

This project has helped us to enrich our database, so we can move forward. Satellite data offers a higher quality of information than we would have previously had access to.

We do need to incorporate other methods to complement this approach though, for example, 70% of our emissions (e.g., transport, livestock) are linked to complicated factors that make this methodology a challenge.

Arturo Palero, Director of Transversal Management in the Face of Climate Change, Government of Jalisco

Key findings in Jalisco's 2021 emissions data

Jalisco's emissions in 2021 are estimated to be 12 million metric tonnes CO_2e (excluding the sectors that Climate TRACE does not currently track and excluding land use change). Of these, biomass loss, road transportation and electricity were the largest emitting sectors in 2021.

Figure 19: *Shows the sectoral breakdown of emissions in Jalisco and Mexico in 2021*

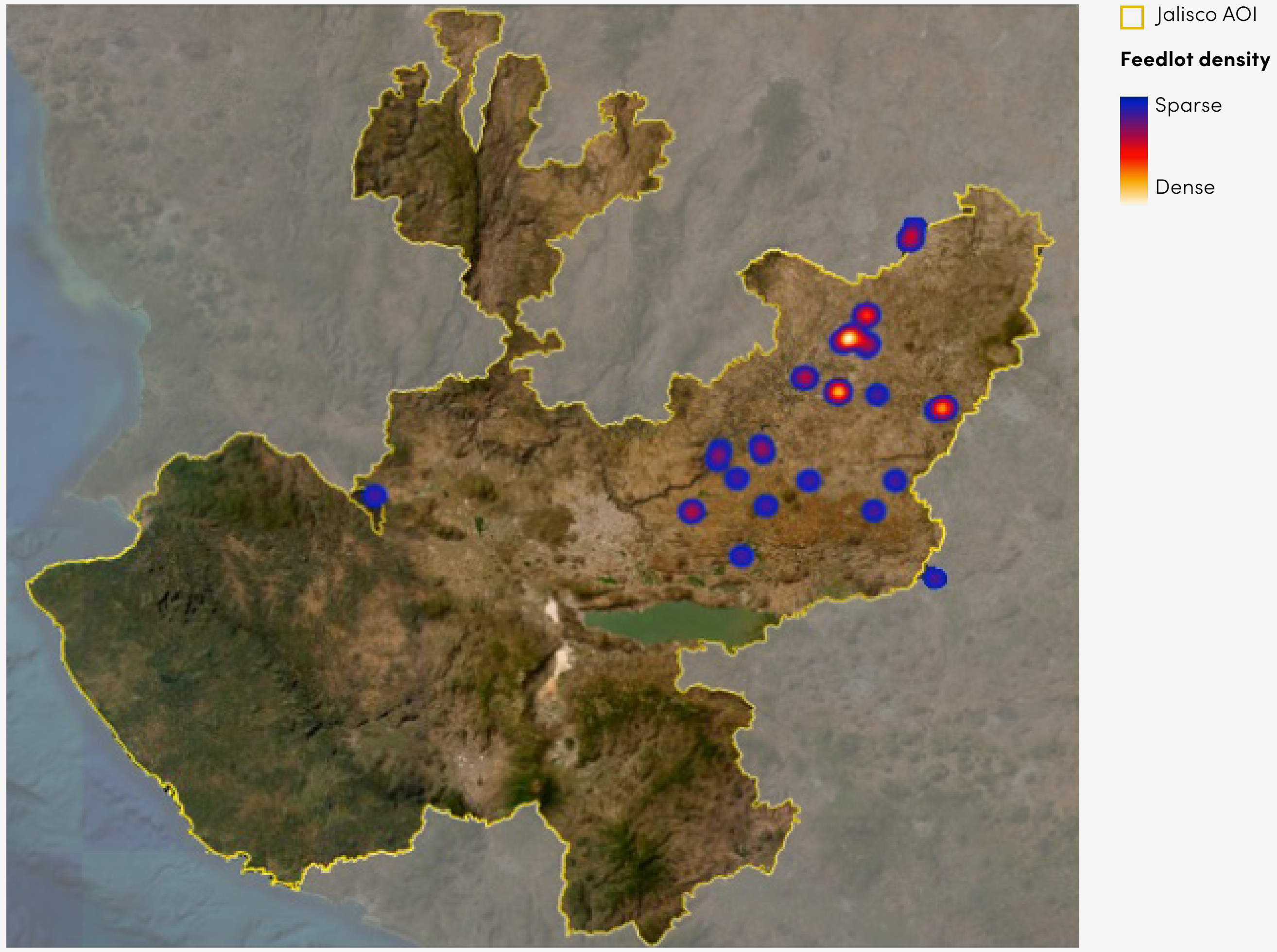
Figure 20: Jalisco's road transport emissions CO_2e in 2021

Road transport

Transport is a main source of emissions for Jalisco. The city of Guadalajara is responsible for 60% of urban road transport emissions in the state.

Figure 20: *Shows the emissions from road transport Jalisco's cities in 2021*

Figure 22: Jalisco feedlot density map



Feedlots

Emissions from feedlots have typically been hard to measure due to a lack of sufficient data sources. However, Climate TRACE has provided a clearer picture of the sector using a combination of satellite imagery and AI. Satellite data reveal that feedlots are mainly concentrated in the north-eastern part of the province. A total of 36 feedlots were identified: 24 beef, five dairy and seven that may be a mix of beef and dairy feedlots. Climate TRACE estimates that these feedlots hold approximately 200,000 head of cattle. For methane emissions, this has a big impact. Typically, one cow produces 99kg of methane a year through enteric fermentation and manure.[9] Given the number of cattle in Jalisco, this equates to roughly 19.8 million kg of methane per year.

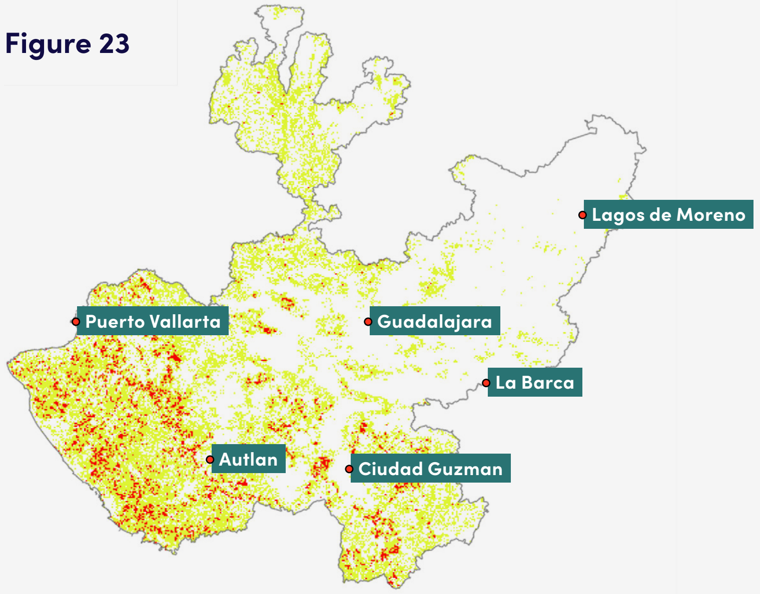
Figure 22: *Jalisco feedlot density map. The majority of the feedlots identified are concentrated in the western region*

Land use change

Forest, wetlands, and shrubland-grassland

Jalisco experienced a net loss in forest and shrubland-grassland biomass between 2015 to 2021. This means an increase in emissions. Forest loss resulted in the release of 80 million tonnes of CO_2e, mainly concentrated in the western region. And shrubland-grassland loss caused the release of six million tonnes of CO_2e from 2015 to 2021, mainly concentrated in the northern part of the region. Climate TRACE data suggest this loss is primarily driven by deforestation and degradation.

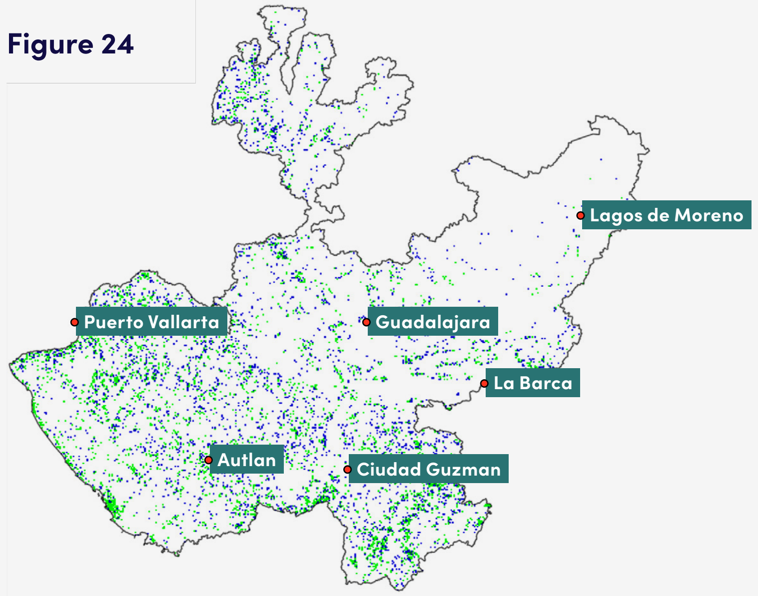
Figure 23



1000 to 7000   >7000

Figure 23: *Jalisco forest land biomass loss between 2015 and 2021. Legend value ranges from 1,000 to 7,000 (yellow) and >7,000 (red, largest emissions increase) tonnes of CO_2e.*

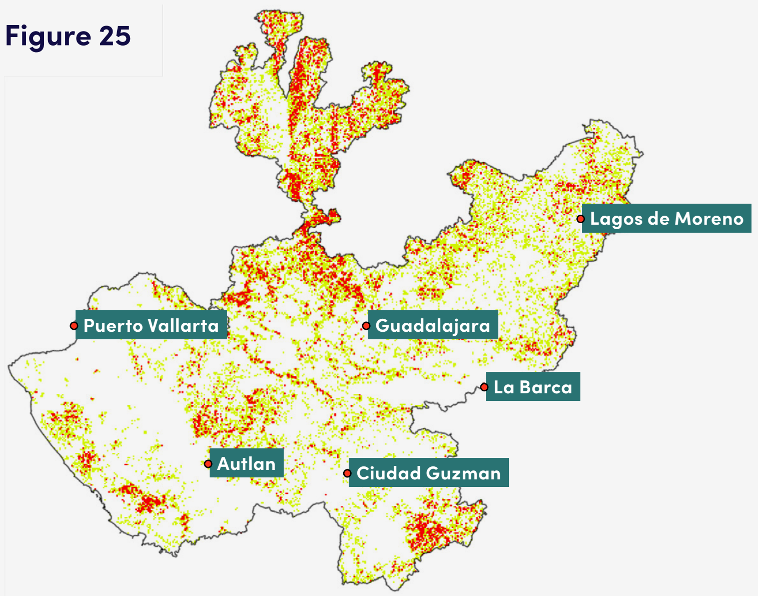
Figure 24



< -2000   -2000 to -1000

Figure 24: *Jalisco forest land biomass gain between 2015 and 2021. Legend value ranges from <-2,000 (green, largest emissions decrease) and −2,000 to −1,000 (blue) tonnes of CO_2e.*

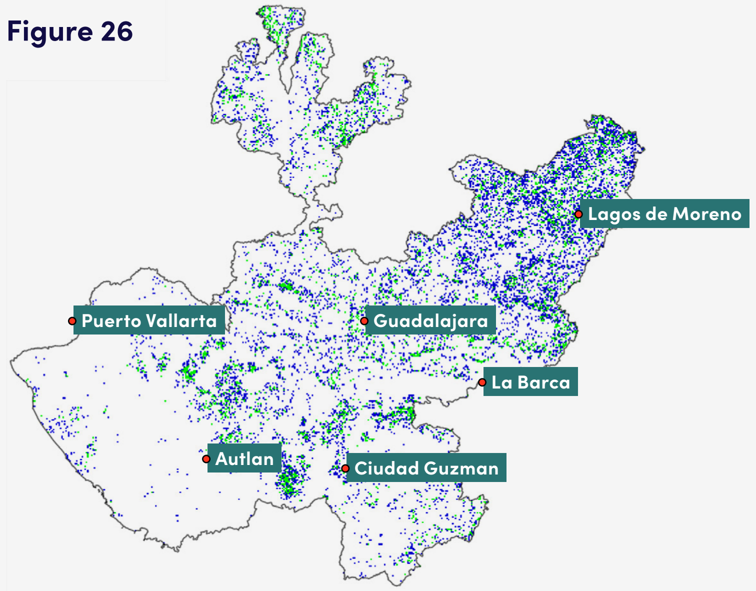
Figure 25



100 to 750   >750

Figure 25: *Jalisco shrubland-grassland biomass loss between 2015 and 2021. Legend value ranges from 100 to 750 (yellow) and >750 (red, largest emissions increase) tonnes of CO_2e.*

Figure 26



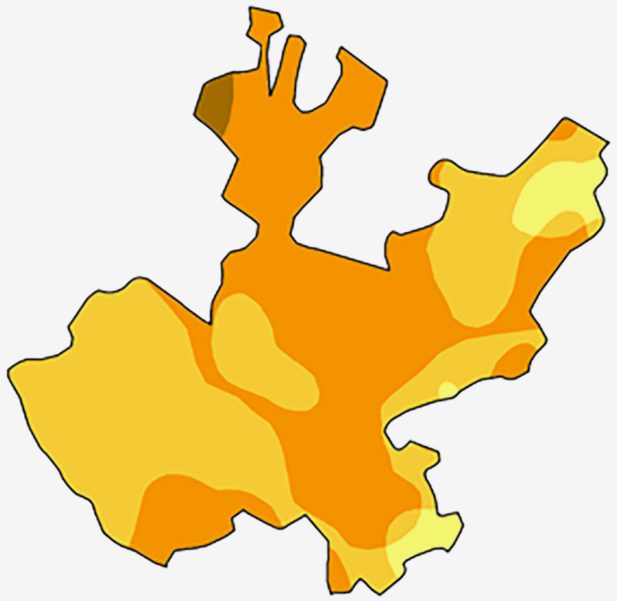
< -500   -500 to -100

Figure 26: *Jalisco shrubland-grassland biomass gain between 2015 and 2021. Legend value ranges from <-500 (green, largest emissions decrease) and -500 to -100 (blue) tonnes of CO_2e.*

The emissions findings for the areas impacted by degradation are consistent with the expected changes in biomass. This is due to more droughts between 2015 and 2021. The drought class maps below show degradation intensity or improvement.

Comparing Jalisco drought conditions in 2021 to 2020 shows that the region was in some form of drought-induced degradation. Comparing 2016 to 2015 drought conditions shows that central Jalisco was in a lower state of degradation.

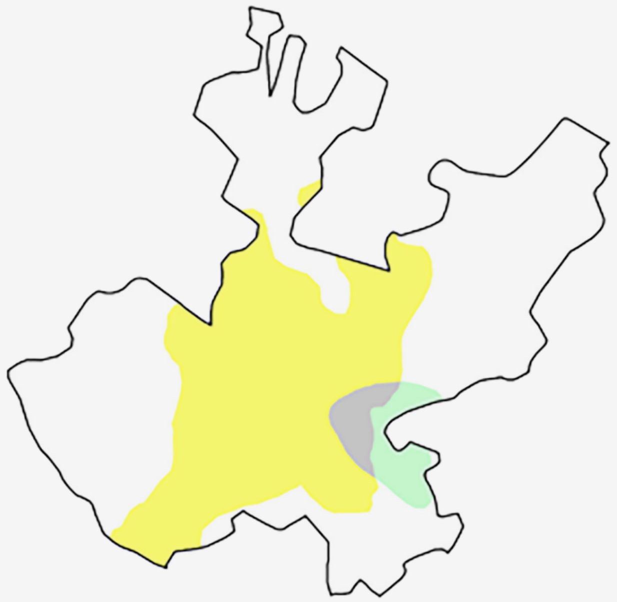
Figure 27: North American drought monitor class change – Jalisco, Mexico – one year



5 Class Degradation
4 Class Degradation
3 Class Degradation
2 Class Degradation
1 Class Degradation
No Change
1 Class Improvement
2 Class Improvement
3 Class Improvement
4 Class Improvement
5 Class Improvement

Figure 27: *Jalisco drought monitor class changes for 31 May 2021 compared to 21 May 2020. Maps are generated from the National Drought Mitigation Center (drought.unl.edu/)*

Figure 28: North American drought monitor class change – Jalisco, Mexico – one year



5 Class Degradation
4 Class Degradation
3 Class Degradation
2 Class Degradation
1 Class Degradation
No Change
1 Class Improvement
2 Class Improvement
3 Class Improvement
4 Class Improvement
5 Class Improvement

Figure 28: *Jalisco drought monitor class changes for 31 May 2016 compared to 31 May 2015. Maps are generated from the National Drought Mitigation Center (drought.unl.edu/)*

Pernambuco, Brazil

Pernambuco, Brazil

Overview

Pernambuco is the seventh most populous state in Brazil, located in the northeast region of the country. The economy is based on agriculture, livestock farming, and industry.

In 2022, the state published a Decarbonisation Plan[10], setting out measures to achieve carbon neutrality by 2050 with a focus on the energy, industry, transport, waste and AFOLU sectors. This plan includes short-, medium-, and long-term targets, as well as actions for each sector.

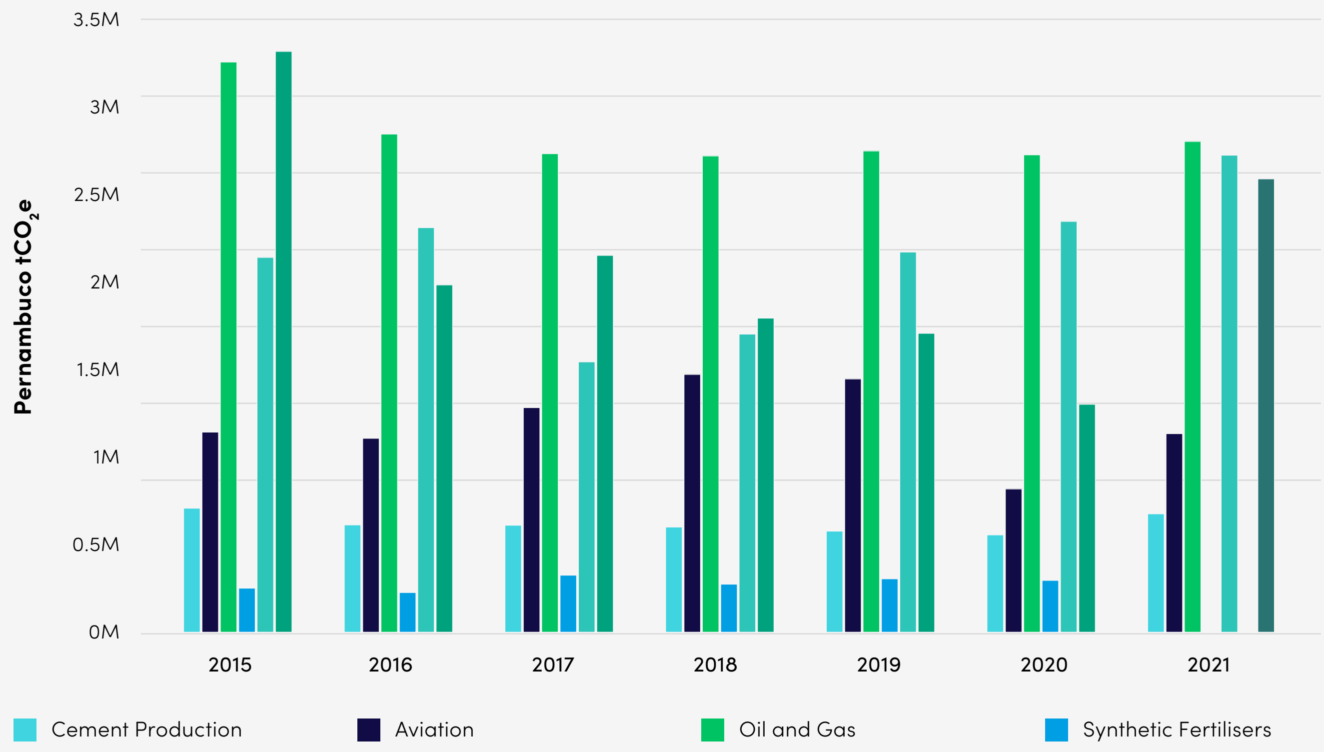
Pernambuco was the first state in Brazil to develop its first GHG inventory through participation in the Climate Group's Climate Footprint Project[11] in 2019. Through its Under2 Coalition membership, the state has committed to net zero emissions by 2050.

Last available inventories

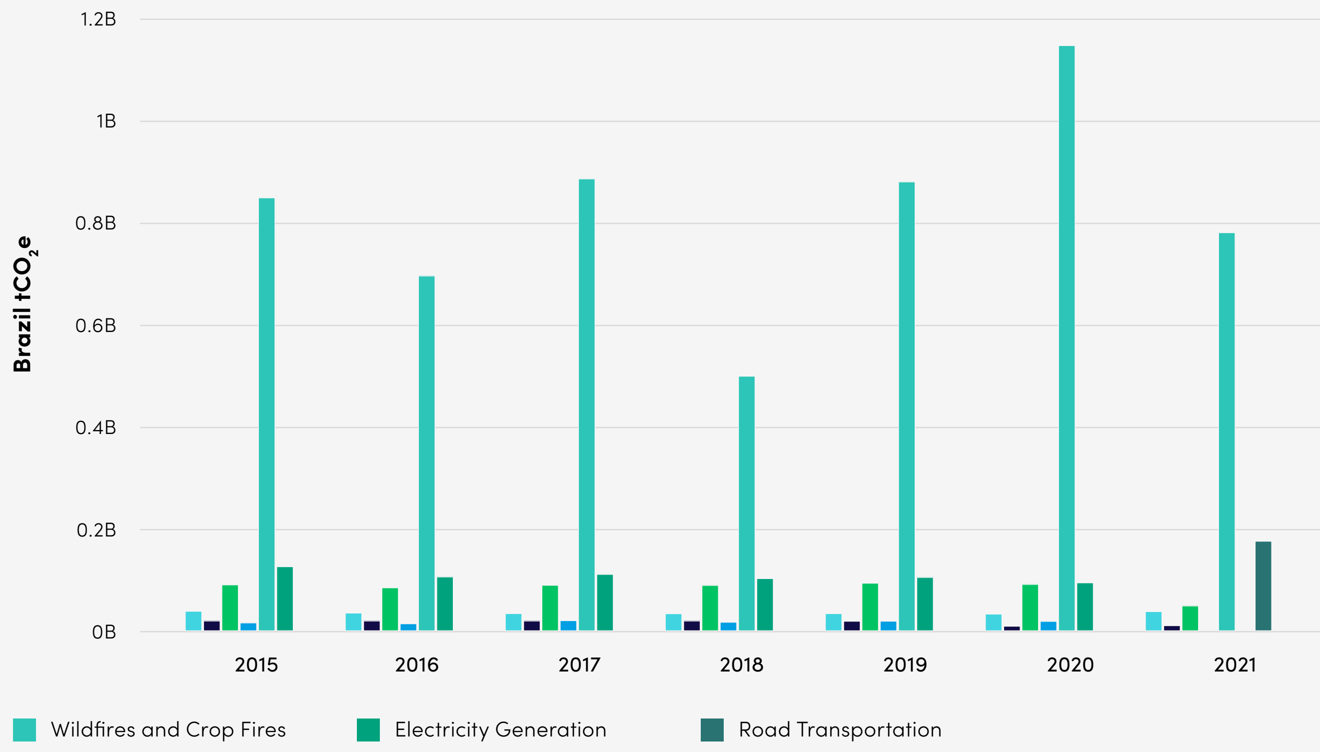
2015–2020

Figure 29: Comparing emissions sources at the local and national levels

Pernambuco



Brazil



Data Source: Climate TRACE

Why STARRS?

Pernambuco joined the STARRS project to improve its understanding of GHG emissions, particularly at the sub sectoral level. The state also wanted to compare the data provided by Climate TRACE with its current inventory to spot any gaps or inconsistencies.

The main challenge we face is collecting data. And we need data to develop more agile and efficient systems and methodologies. Joining the STARRS project has given us a means to tackle this problem.

The preliminary data from Climate TRACE has offered some really interesting findings. For example, emissions from the cement industry are much higher than we estimated, and we think this is because we've got yearly gaps in our original inventory.

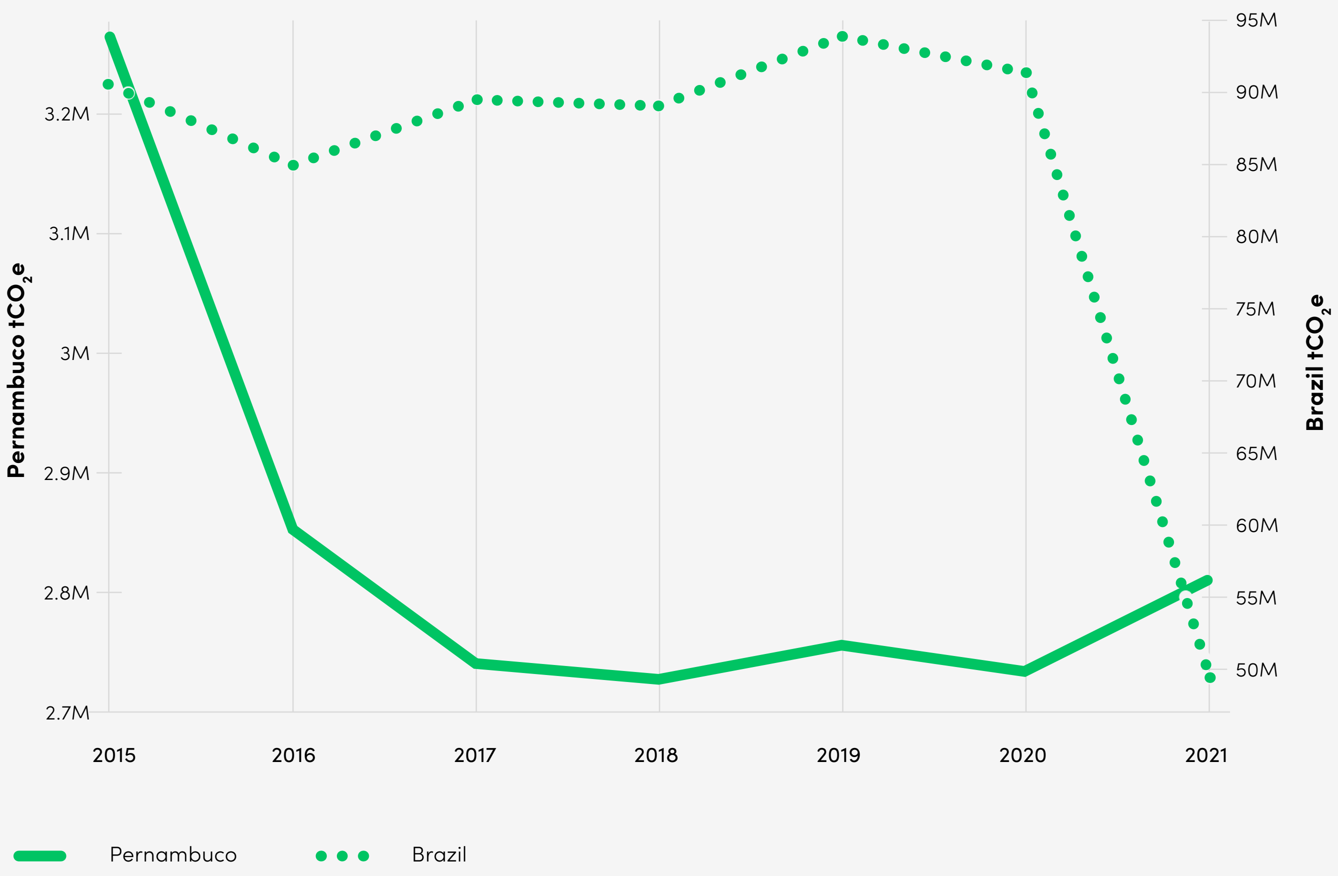
Samanta Della Bella, Superintendent of Sustainability and Climate, Government of Pernambuco

Key findings in Pernambuco's 2021 emissions data

Pernambuco's emissions in 2021 are estimated to be 10.7 million metric tonnes CO_2e (excluding the sectors that Climate TRACE does not currently track and excluding land use change). Of these, biomass loss, road transportation and electricity were the largest emitting sectors in 2021.

Figure 29: *Shows the sectoral breakdown of emissions in Pernambuco and Brazil in 2021*

Figure 30: Comparing emissions sources at the local and national levels



Oil and gas

Refined petroleum is one of Pernambuco's top exports. The largest refinery in the region is the Petrobras RNEST refinery located in the eastern part of the state. It emits nearly three million tonnes of CO_2e annually. Whereas only 2% of Brazil's total emissions are from oil and gas refining, 27% of Pernambuco's emissions come from the sector. In addition, historical trends at the state and national level have differed significantly.

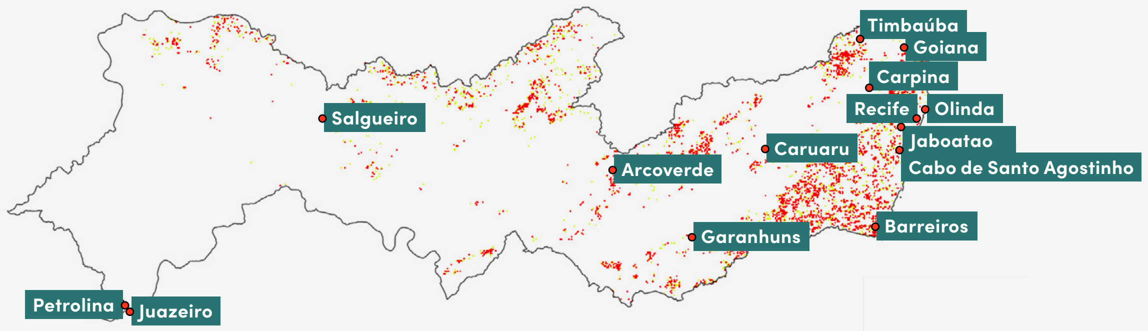
Figure 30: *Shows the change in emissions over time from oil and gas, comparing Pernambuco and Brazil*

Land use change

Forest, wetlands, and shrubland-grassland

Pernambuco forest (including mangroves) and shrubland-grassland areas experienced an overall biomass increase from 2015 to 2021. This sequestered ~three million and ~32 million tonnes of CO_2e, respectively. Forest biomass loss and consequent emissions were concentrated in a relatively small region of the state, mostly near the border of Ceará state and around the Araripe-Apodi National Forest. Shrubland-grassland gain was mainly concentrated to the west from the Atlantic coast.

Figure 31

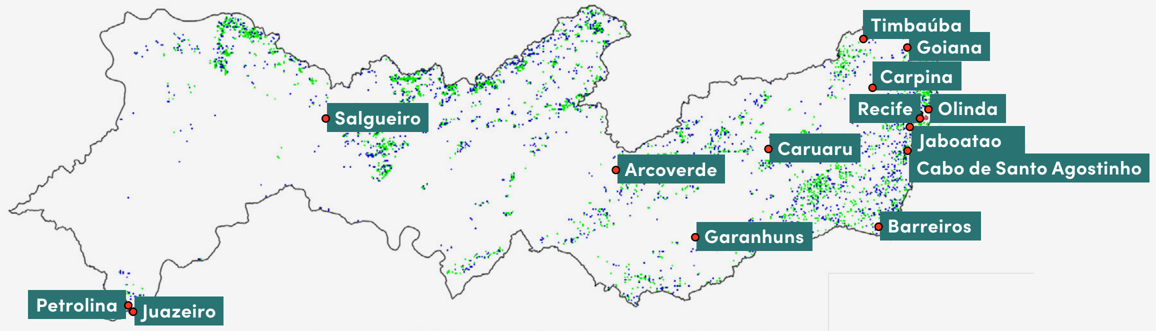


1000 to 1500

>1500

Figure 31: Pernambuco forest land biomass loss between 2015 and 2021. Legend value ranges from 1,000 to 1,500 (yellow) and >1,500 (red, largest emissions increase) tonnes of CO_2e.

Figure 32

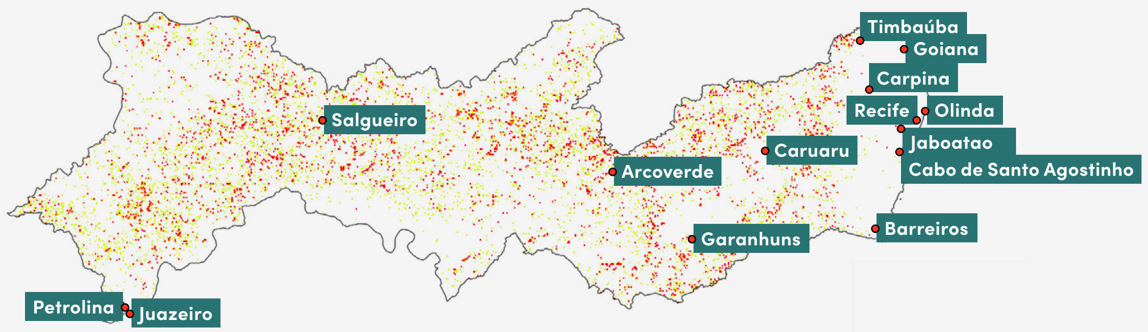


< -2000

-2000 to -1000

Figure 32: Pernambuco forest land biomass gain between 2015 and 2021. Legend value ranges from <-2,000 (green, largest emissions decrease) and -2,000 to -1,000 (blue) tonnes of CO_2e.

Figure 33

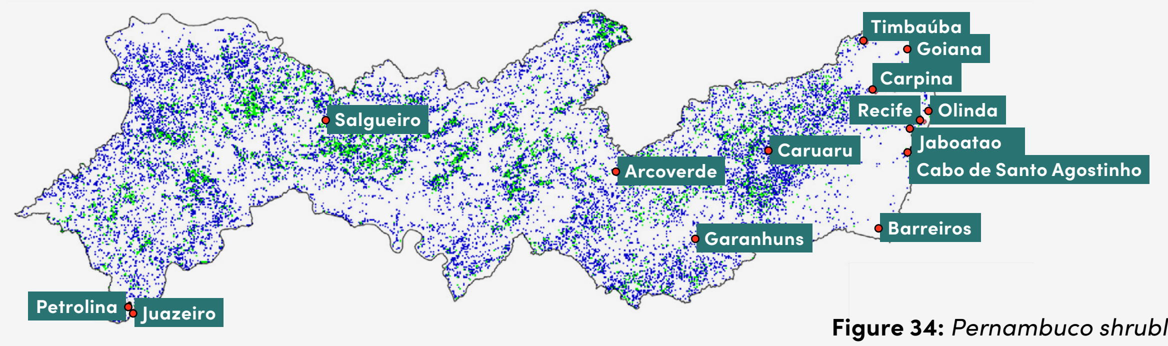


1000 to 1500

>1500

Figure 33: Pernambuco shrubland-grassland biomass loss between 2015 and 2021. Legend value ranges from 1,000 to 1,500 (yellow) and >1,500 (red, largest emissions increase) tonnes of CO_2e.

Figure34

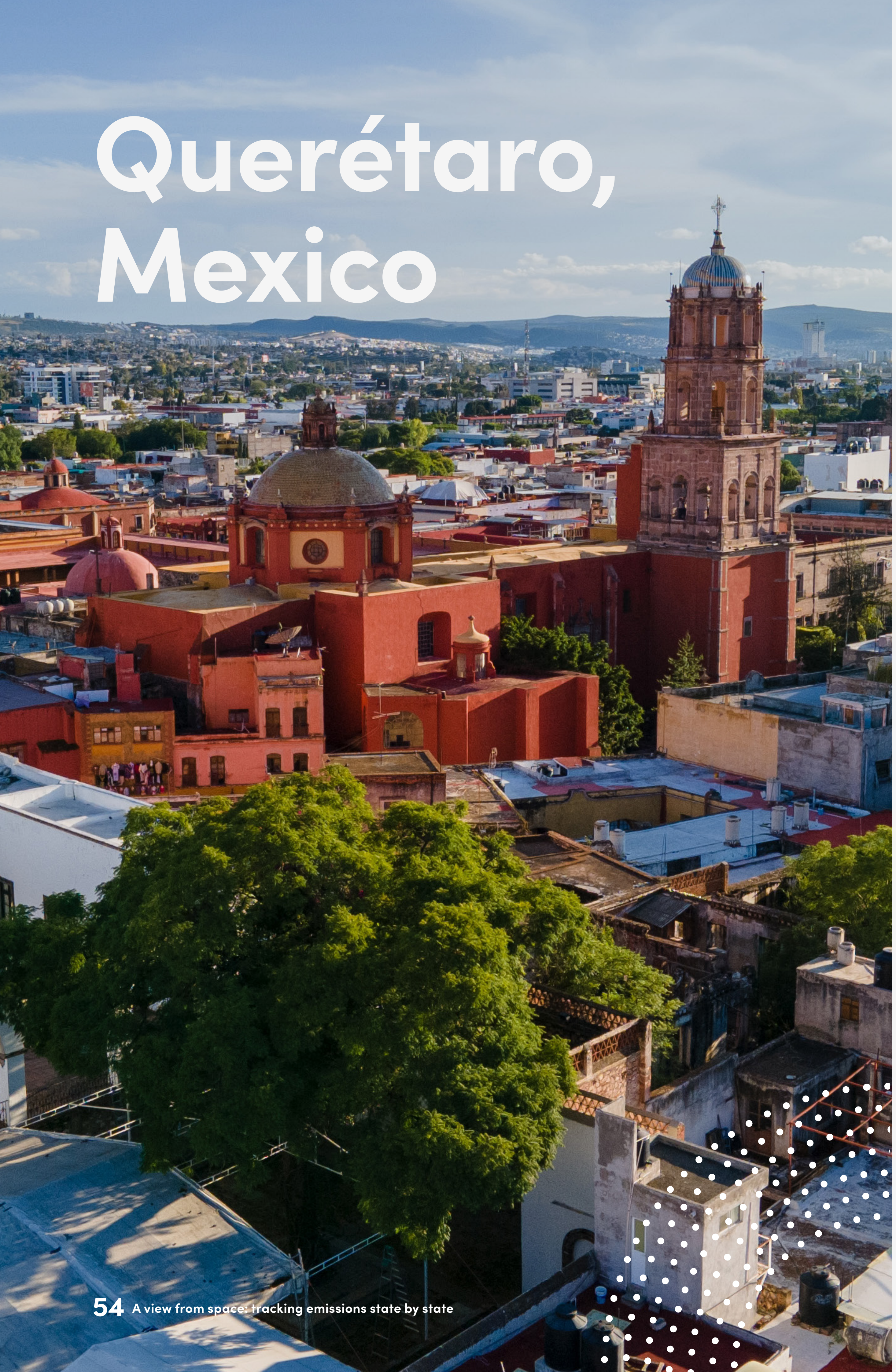


< -3000

-3000 to -1000

Figure 34: Pernambuco shrubland-grassland biomass gain between 2015 and 2021. Legend value ranges from <-3,000 (green, largest emissions decrease) and -3,000 to -1,000 (blue) tonnes of CO_2e.

Querétaro, Mexico



Querétaro, Mexico

Overview

Querétaro is located in the centre of Mexico and is divided into 18 municipalities. According to data from the Economic Census 2019, the main economic sectors in the state are retail trade; accommodation and food services; and manufacturing industries.[12]

In the state's latest GHG inventory, published in 2015, the energy sector was the largest contributor of GHG emissions (84.5%). This was followed by agriculture, forestry and other land use (AFOLU) (8.2%), waste (4.9%) and industrial processes and use of products (IPPU) (2.4%).

According to Querétaro's decarbonisation pathway[13] – developed with support from the Under2 Coalition – it's projected that without policies to reduce emissions, the region will emit 33.5 million tonnes of CO_2e by 2050. This would be an increase of 12.5 million tonnes CO_2e since 2015.

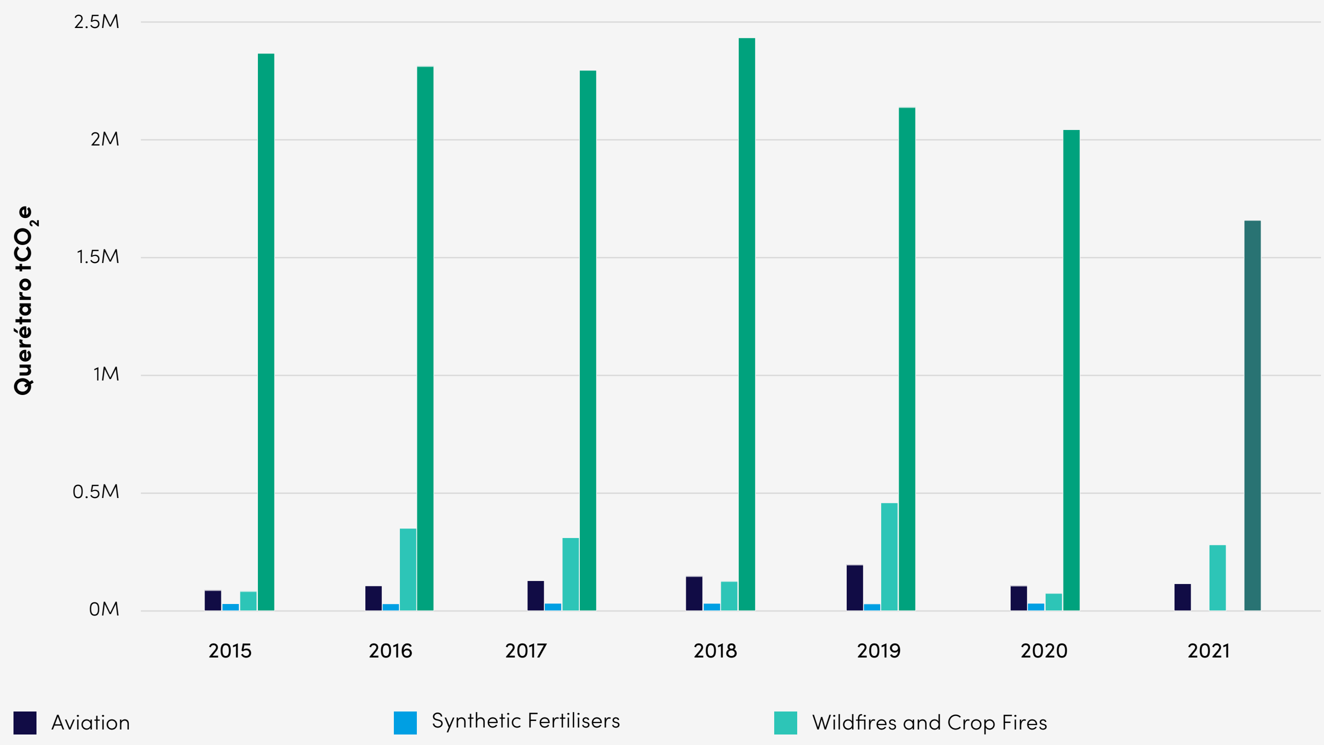
In 2018, the state published its Climate Change Law that aims to help coordinate policymaking across different state-level departments to ensure a joined-up approach for adaptation and mitigation measures.

Last available inventories

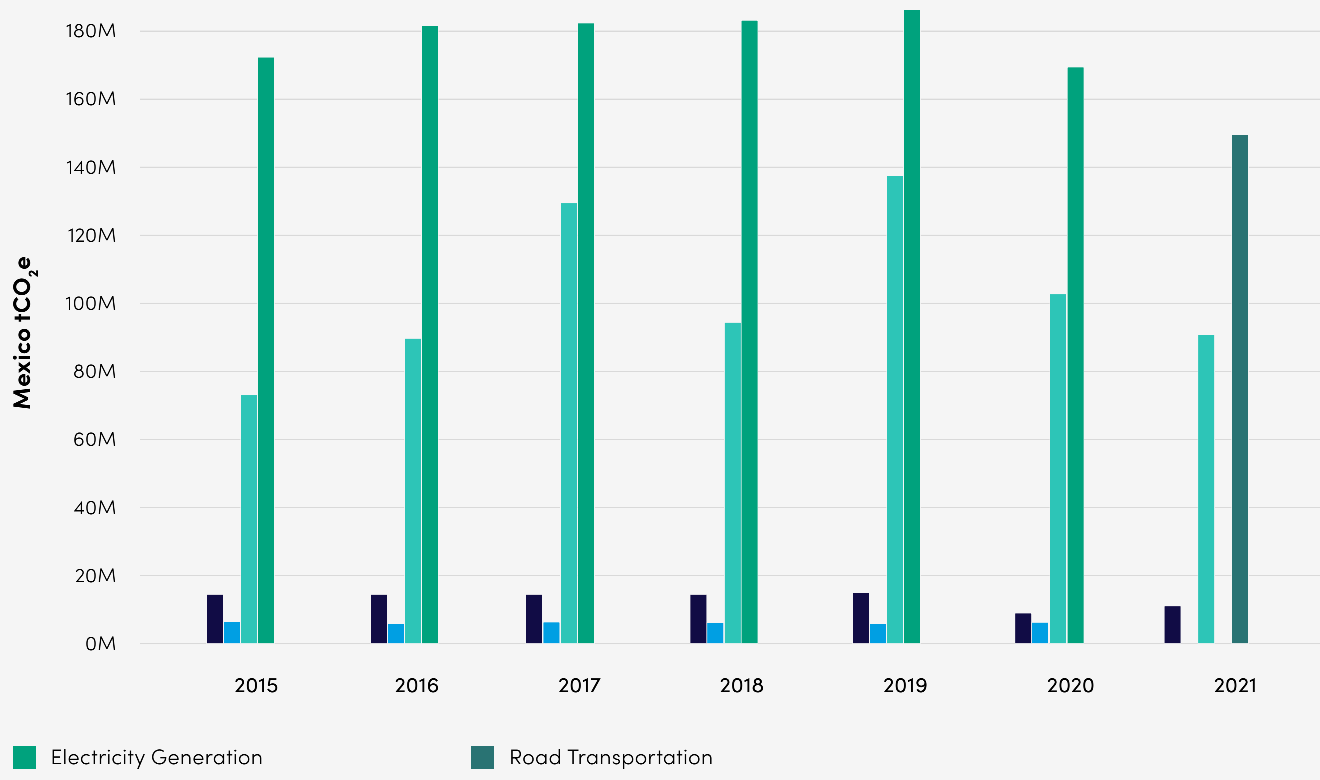
2015

Figure 35: Comparing emissions sources at the local and national levels

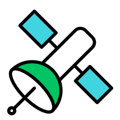
Querétaro



Mexico



Data Source: Climate TRACE



Why STARRS?

Traditional methods to collect emissions data are slow, particularly at the subnational level. Querétaro joined the STARRS project to improve the speed in which it can collect reliable emissions data, and in doing so, make policy design and implementation more efficient.

In Querétaro, we've been developing inventories the same way for 30 years. We joined this project because we need new methods to provide accurate and consistent data, faster.

It takes a year, and costs around $100,000 to produce an emissions inventory in Querétaro. Using this technology will help us to do it faster and save costs.

These data will help us with decision making – particularly with developing pathways and decarbonisation strategies.

Ricardo Javier Torres Hernández, Undersecretary of Environment, Government of Querétaro

Key findings in Querétaro's 2021 emissions data

Querétaro's emissions in 2021 are estimated to be 4.3 million metric tonnes CO_2e (excluding the sectors that Climate TRACE does not currently track and excluding land use change). Of these, biomass loss, road transportation and electricity were the largest emitting sectors in 2021.

Figure 35: *Shows the sectoral breakdown of emissions in Querétaro and Mexico in 2021*

Land use change

Forest, wetlands, and shrubland-grassland

Between 2015 and 2021, Querétaro experienced a net biomass loss across forest (including mangrove) and shrubland-grassland areas. This means an increase in emissions. The estimated loss in forest biomass resulted in the release of ~one million tonnes of CO_2e, mainly concentrated in the north.

Figure 36

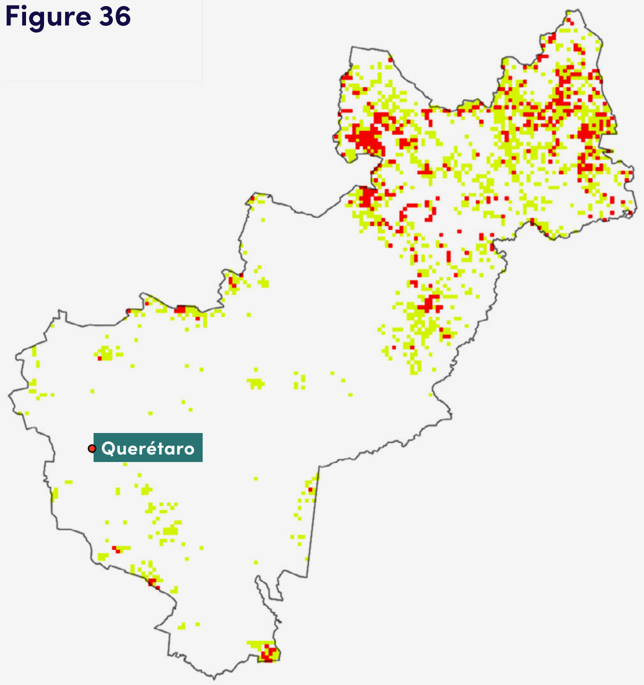


Figure 36: *Querétaro forest land biomass loss between 2015 and 2021. Legend value ranges from 1,000 to 3,500 (yellow) and >3,500 (red, largest emissions increase) tonnes of CO2e.*

Figure 38

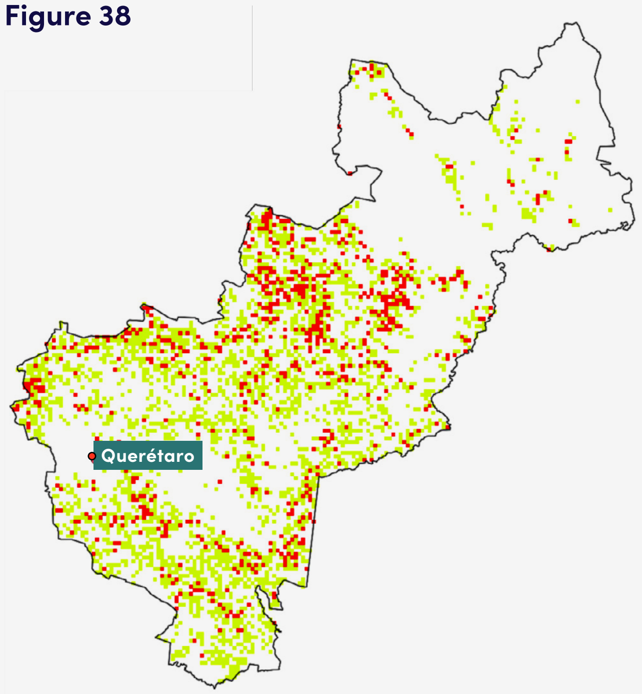


Figure 38: *Querétaro shrubland-grassland biomass loss between 2015 and 2021. Legend value ranges from 100 to 750 (yellow) and >750 (red, largest emissions increase) tonnes of CO_2e.*

Shrubland-grassland loss caused the release of ~68,000 tonnes of CO_2e. A potential driver of biomass loss is drought conditions in the region and throughout Mexico. In fact, they're considered to be the worst conditions in 30 years based on NASA satellite measurements.[14]

Figure 37

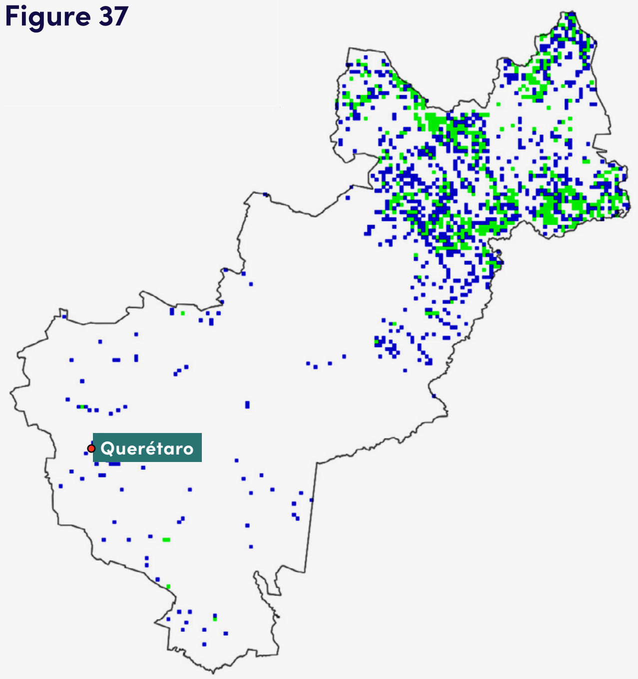


Figure 37: *Querétaro forest land biomass gain between 2015 and 2021. Legend value ranges from <-2,000 (green, largest emissions decrease) and -2,000 to -1,000 (blue) tonnes of CO_2e.*

Figure39

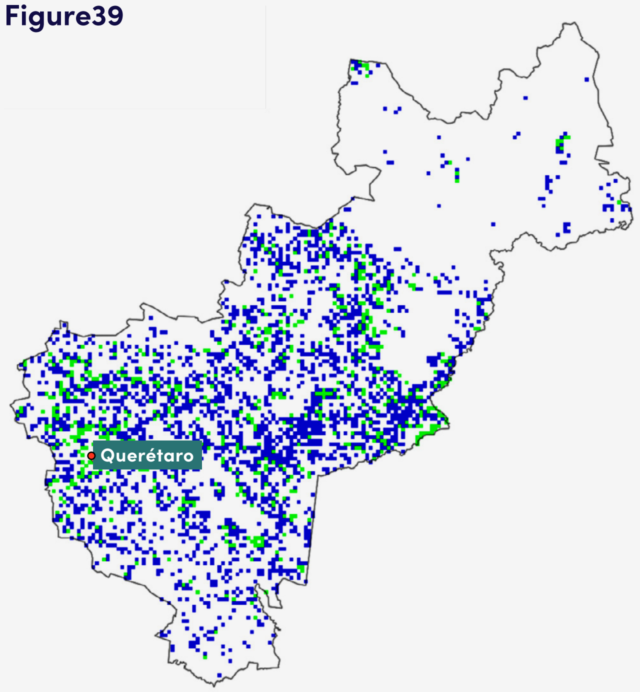


Figure 39: *Querétaro shrubland-grassland biomass gain between 2015 and 2021. Legend value ranges from <-750 (green,largest emissions decrease) and -750 to -100 (blue) tonnes of CO_2e.*

Figure 40: Comparing emissions estimates from ClimateTRACE vs. previous inventories

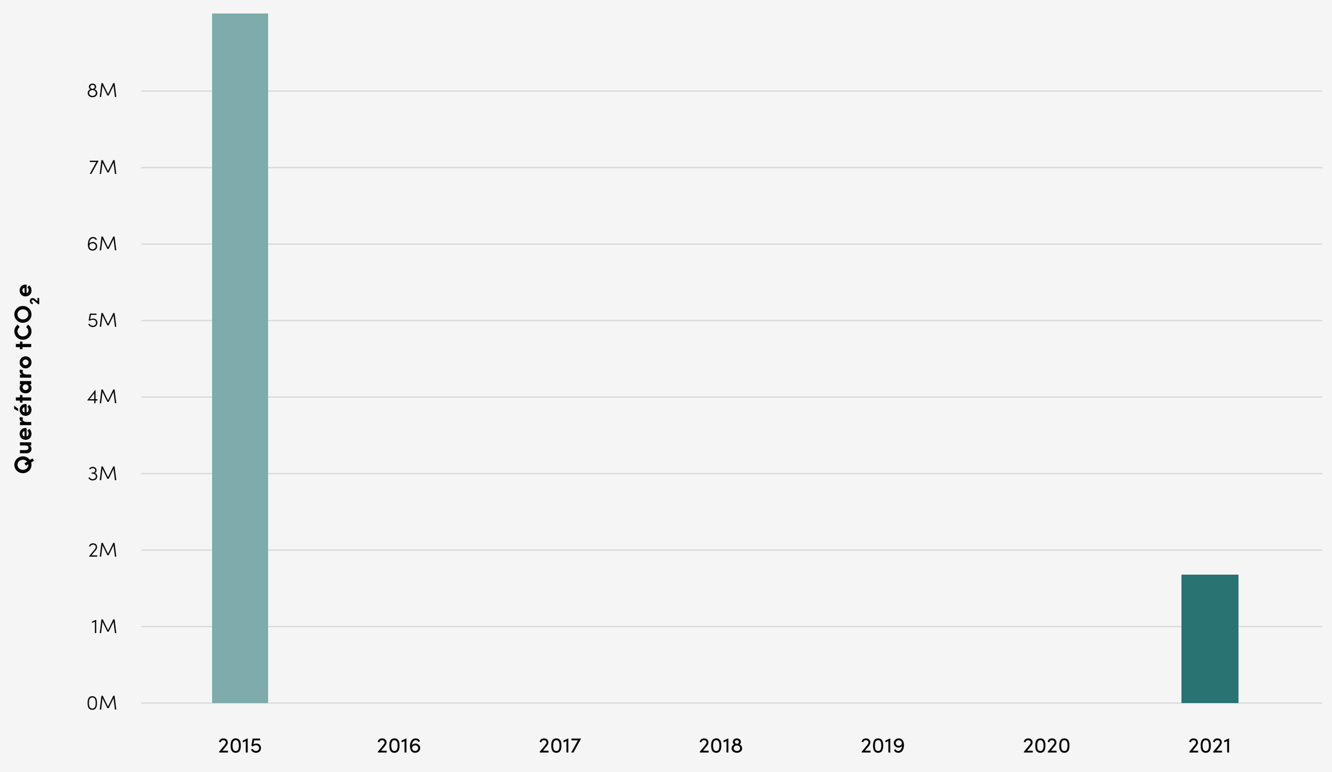
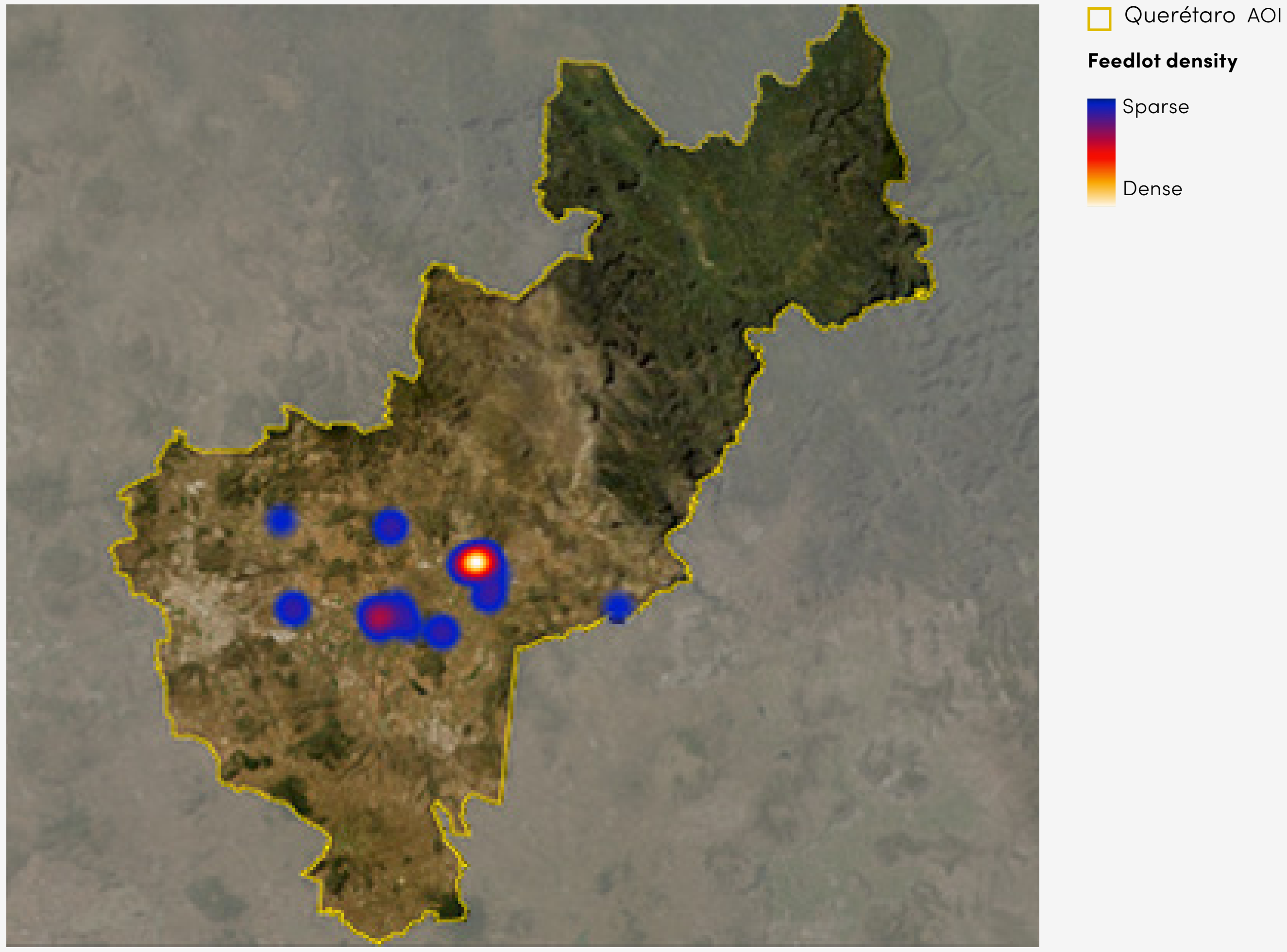


Figure 41: Querétaro feedlot density map



Road transport

Climate TRACE's modelling of emissions is based on satellites and can therefore provide emissions estimates at the municipal level. This is unlike typical IPCC methods, which are calculated based on fuel sales for the entire state. Therefore, they may not be representative of the true road transport emissions in the state.

It's likely that Querétaro have been overestimating its road transport emissions – likely due to this methodology – as can be seen in **Figure 34.**

Figure 40: *Comparing emissions estimates from Climate TRACE versus previous inventories for road transport*

Feedlots

Climate TRACE located 40 feedlots concentrated in the southern half of the province. Of the 40, 28 are beef, 10 are dairy and 2 may be a mix of beef and dairy. Climate TRACE estimates that these feedlots hold approximately 136,000 heads of cattle.

Identifying the location and the type of feedlots is important, as beef and dairy methane and nitrous oxide emissions can differ in total emissions. Dairy is higher than beef. The density of feedlots appear to be localised within the south central region.

Figure 41: *Querétaro feedlot density map. Most of the feedlots identified are concentrated in the central half of the region.*

Western Cape, South Africa

Western Cape, South Africa

Overview

Western Cape has the third largest economy out of South Africa's nine provinces. In the first quarter of 2022, the province contributed approximately 14% to South Africa's GDP.

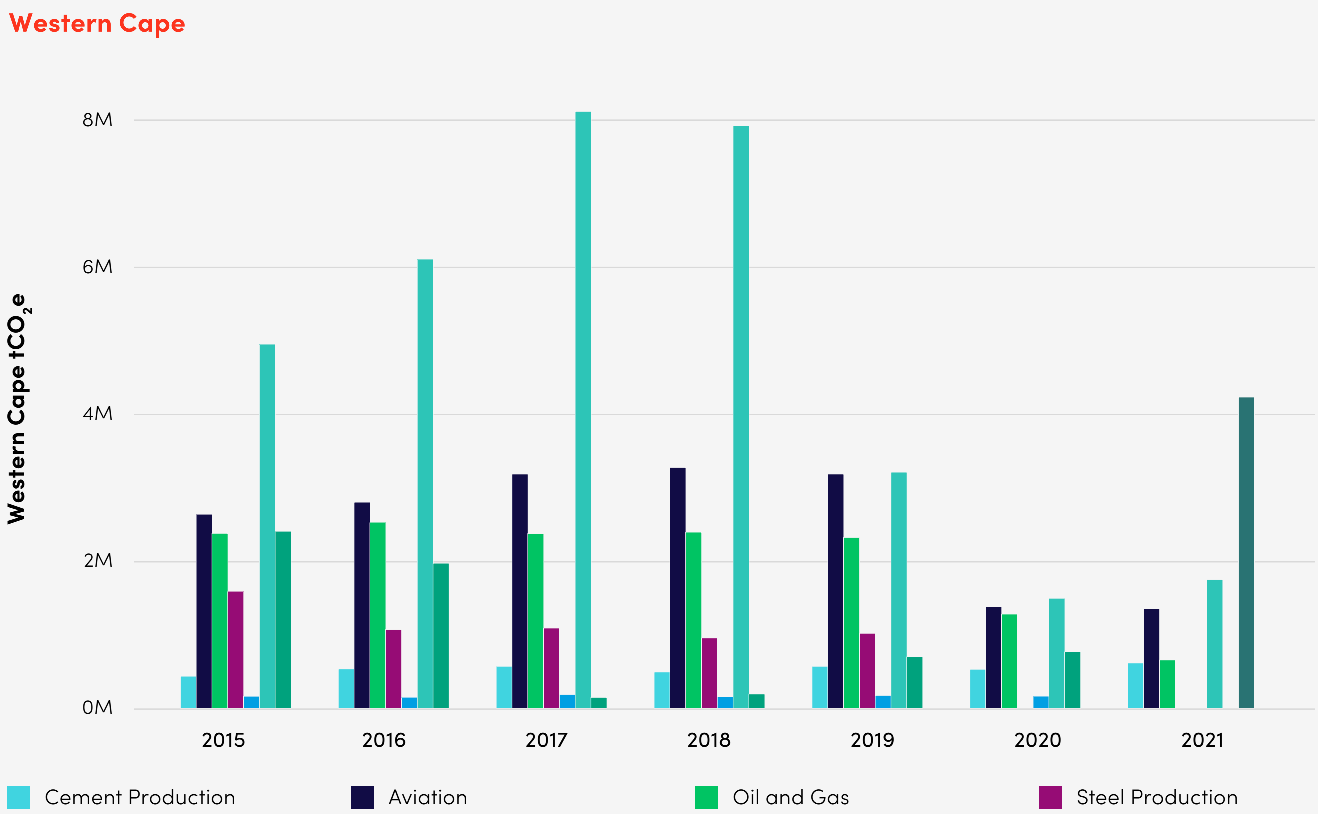
According to previous inventories, most emissions in Western Cape come from transport (54%) and industry (29%). The built environment (both residential and commercial sectors) is responsible for 15% of energy consumption.

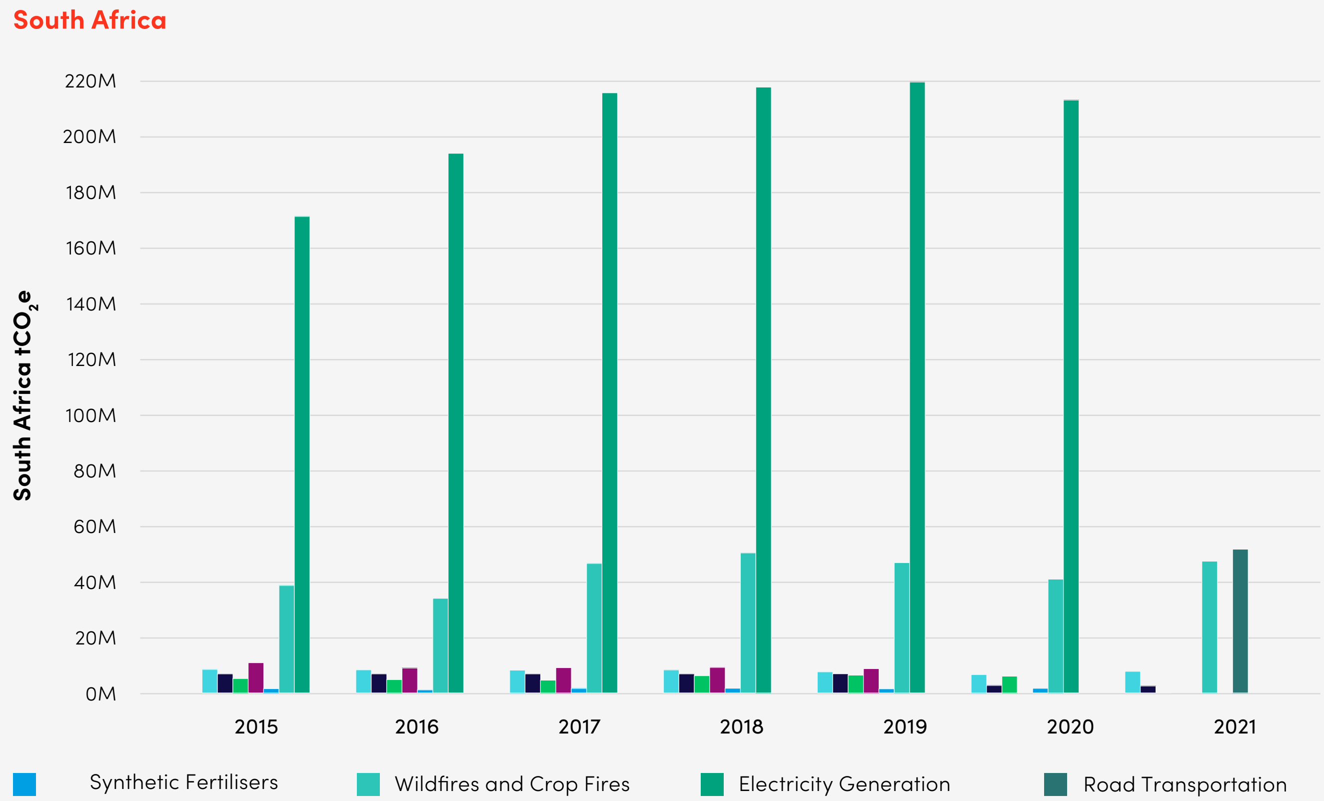
As a member of the Under2 Coalition, Western Cape has committed to reaching net zero by 2050. To achieve this, it's pushing for two crucial transitions. The first is a shift from internal combustion engines to electric mobility, and the second is a shift from fossil-fuel based energy to renewables.

Last available inventories

2009 and 2015–2016

Figure 42: Comparing emissions sources at the local and national levels





Data Source: Climate TRACE

Why STARRS?

Most of the data sources that Western Cape relies on are six years old. The province joined STARRS in the hope of developing a validated, recent time-series database from an independent source. Using Climate TRACE data will help to verify current methods and fill in any data gaps.

Some sectors, like electricity and liquid fuels, rely on nationally generated data, which are usually only released after the fact (in some cases up to two years). It makes so much more sense to have regular data, and to add in that regional perspective. Often national datasets aren't captured in a way that can be used regionally due to different geographical boundaries and data collection methodologies.

The STARRS project allows us to check the data we've got and compare on a like-for-like basis to other regions.

Lize Jennings-Boom, Climate Change Mitigation Programme Manager, Government of Western Cape

Key findings in Western Cape's 2021 emissions data

Western Cape's emissions in 2021 are estimated to be 7.8 million metric tonnes CO_2e (excluding the sectors that Climate TRACE does not currently track and excluding land use change). Of these, road transportation, cement manufacturing and electricity were the largest emitting sectors in 2021.

Figure 42: *Shows the sectoral breakdown of emissions in Western Cape and South Africa in 2021*

Figure 43: Comparing emissions sources at the local and national levels

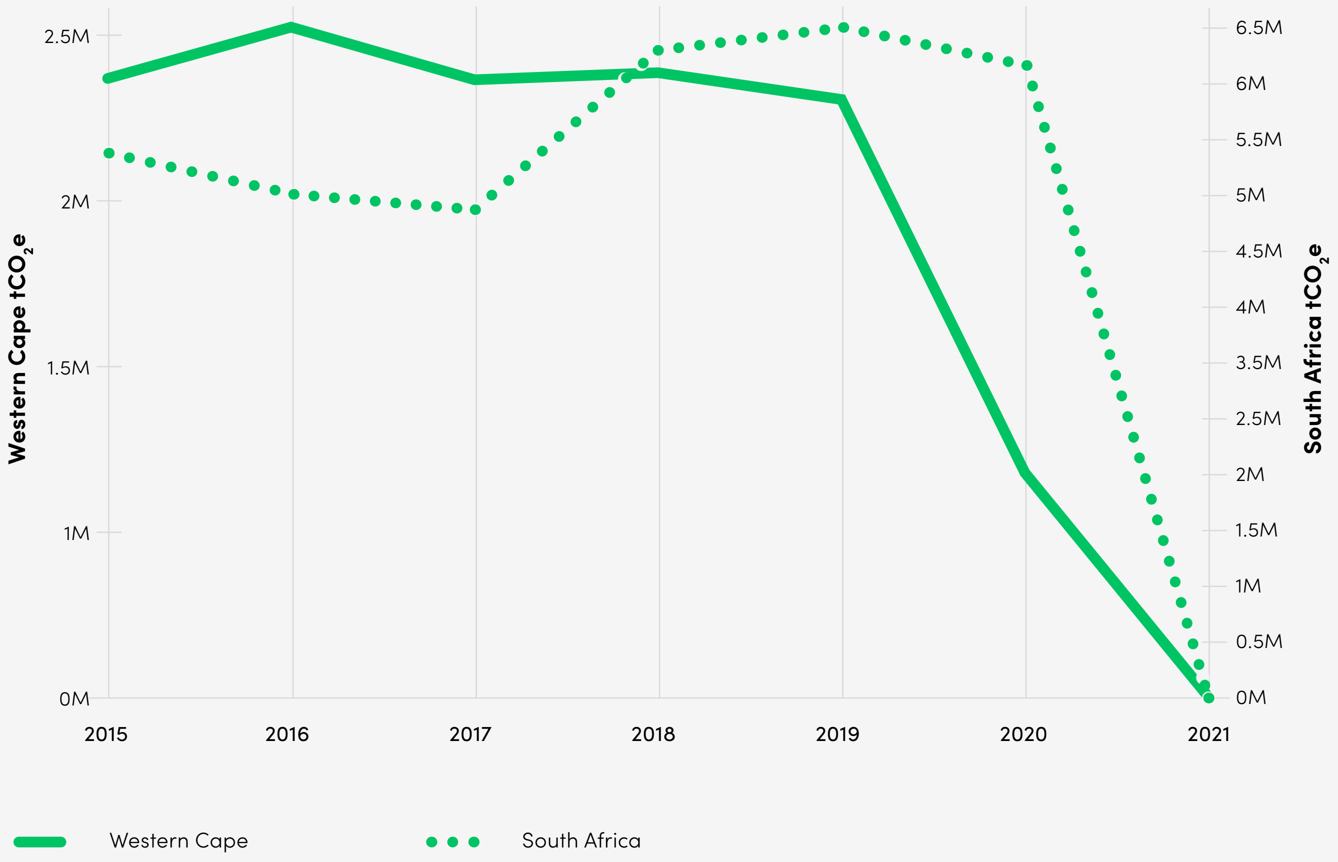
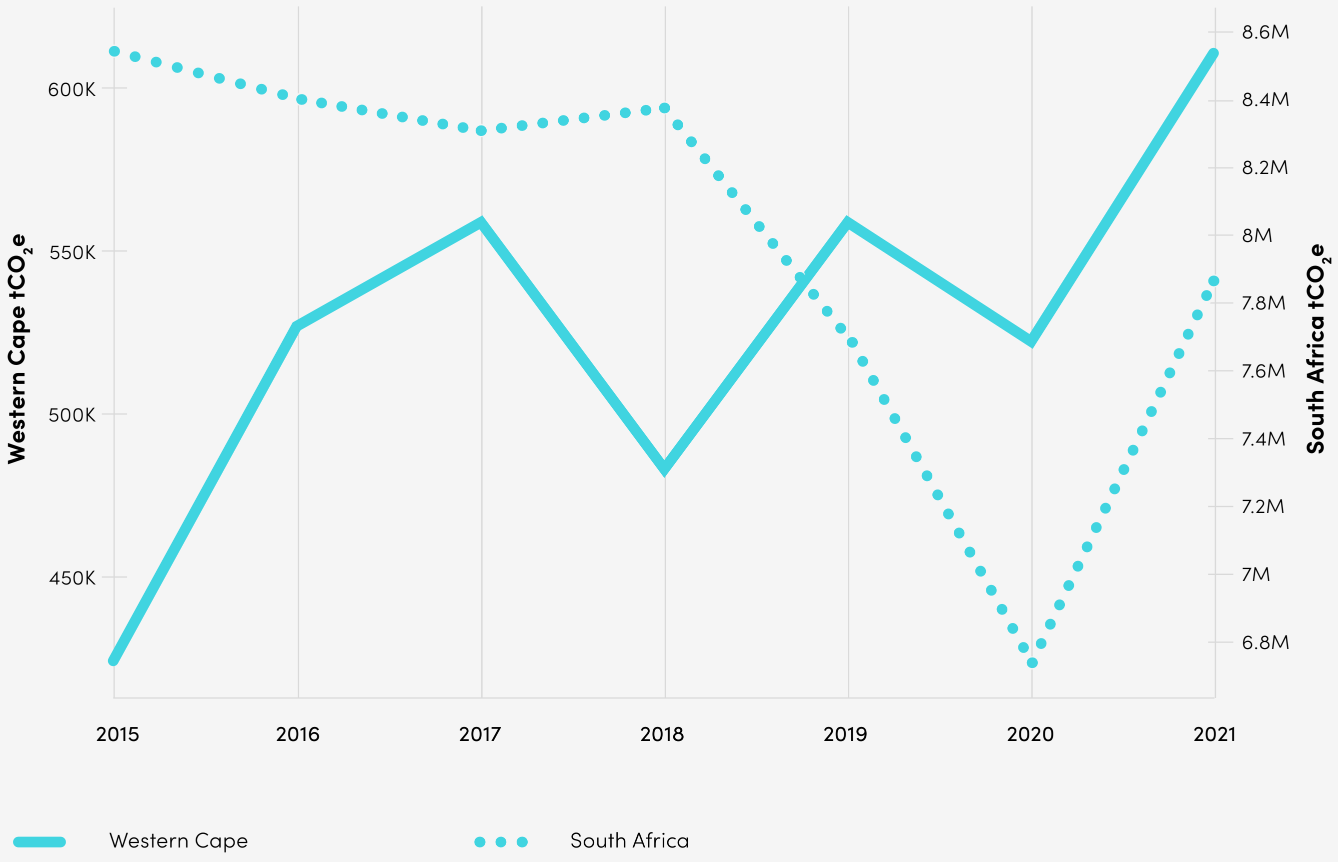


Figure 44: Comparing emissions sources at the local and national levels



Oil and Gas

Nearly 80% of this sector's emissions come from crude oil refining in Western Cape, with two plants located in the state. Declining feedstock and the nationwide shutdown of refineries due to COVID-19 caused emissions to fall between 2019 and 2021. This theme was consistent across state and national levels.

Figure 43: *Shows the change in emissions over time from oil and gas, comparing Western Cape and South Africa*

Cement

Cement manufacturing emissions in the state have remained fairly consistent between 2015 and 2021. Emissions from the single steel plant in the state fell significantly in 2016. The site was finally mothballed in 2019 for economic reasons.

Figure 44: *Shows the change in emissions over time from cement manufacturing in Western Cape and South Africa*

Figure 45: Western Cape road transport emissions CO_2e in 2021

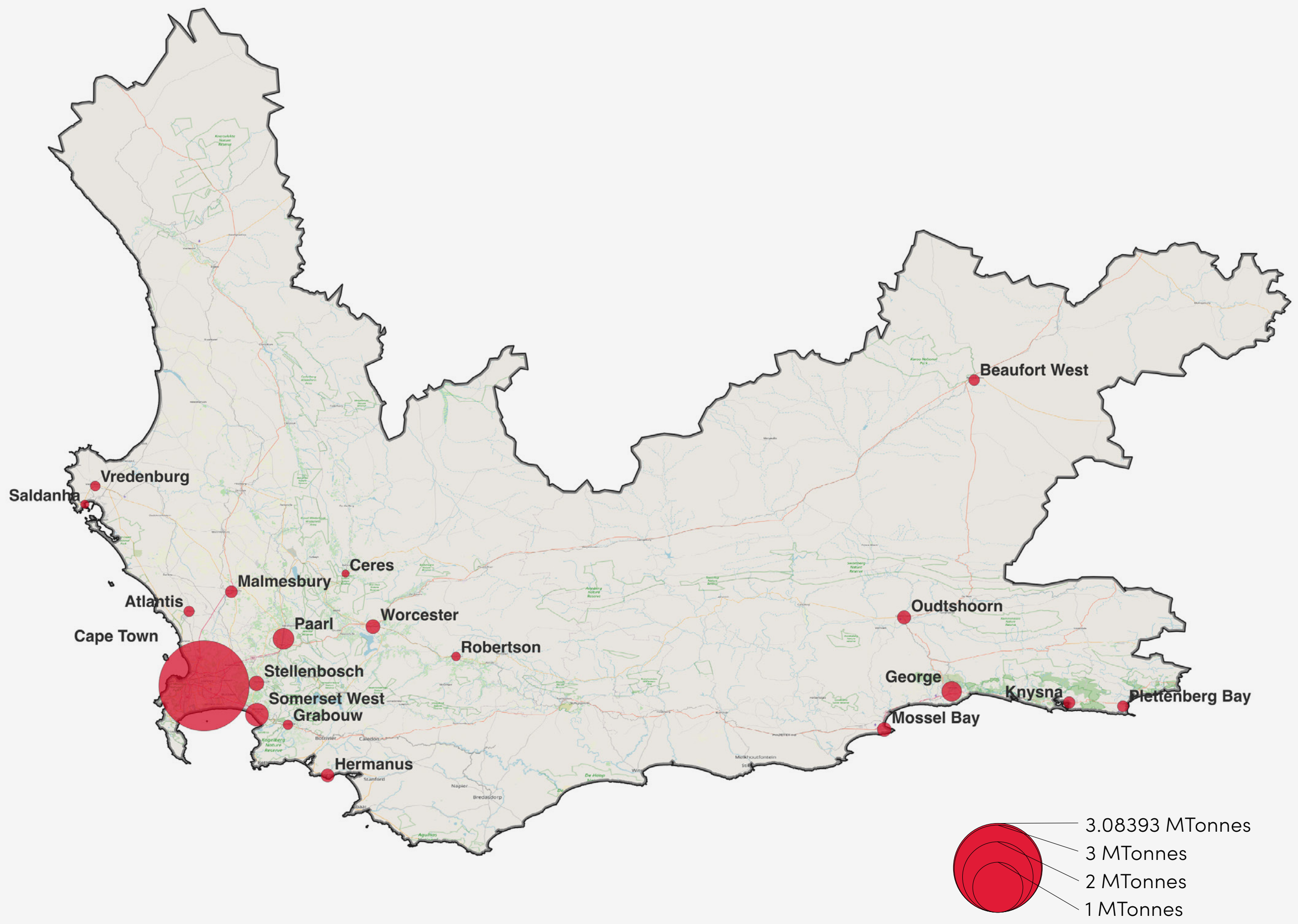
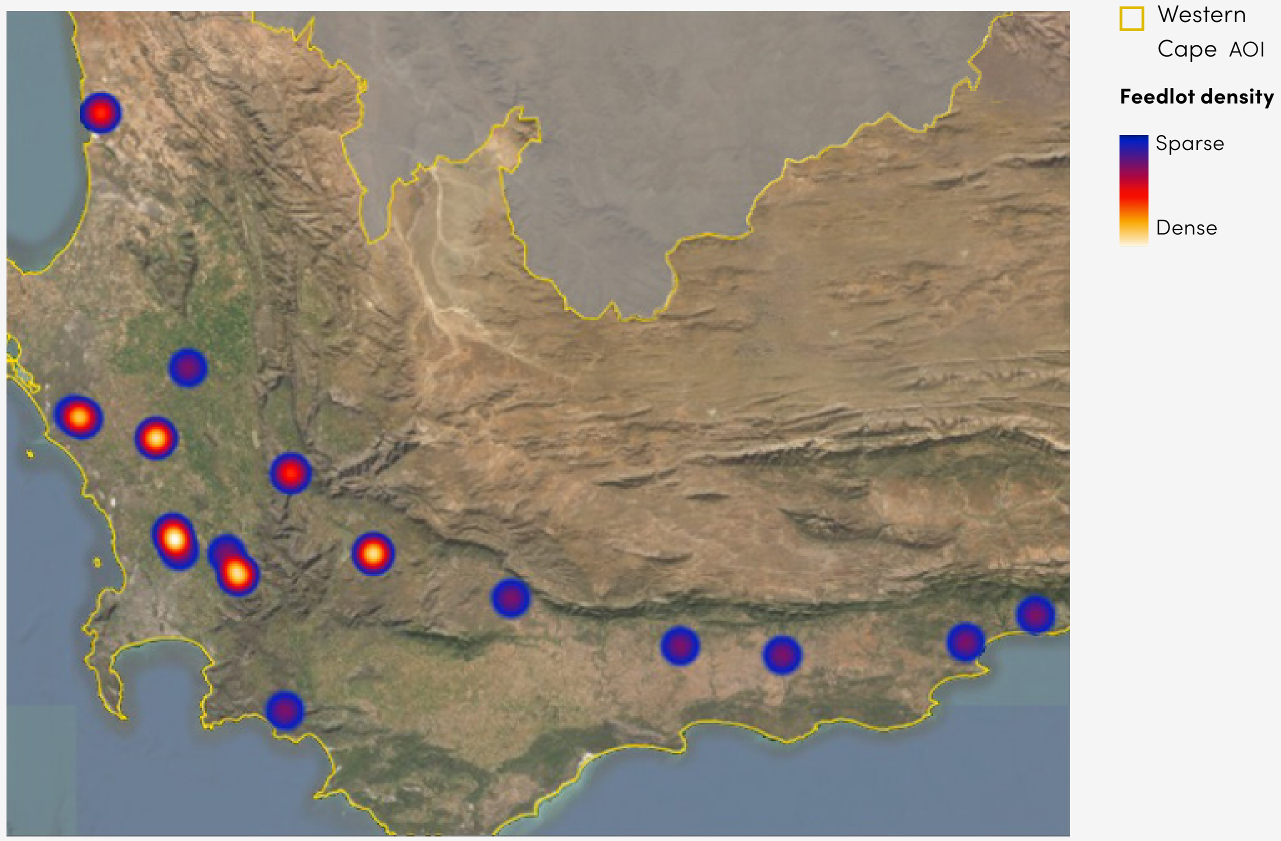


Figure 46: Western Cape feedlot density map



Road transport

Over 70% of urban road transport emissions in the state come from the city of Cape Town – the state's largest city by far.

Figure 45: *Shows the emissions from road transport from Western Cape's cities in 2021*

Animal feedlots

Climate TRACE's AI-based method located 42 large beef and dairy feedlots concentrated in the western part of the province, near Cape Town. Of the 42, 5 are beef, 34 are dairy, and 3 may be a mix of beef and dairy, all of which are estimated to contain ~80,000 head of cattle.

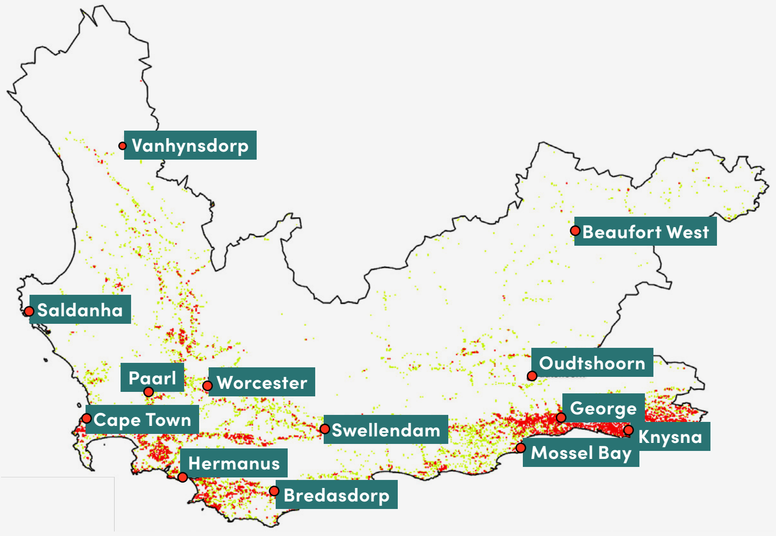
Figure 46: *Western Cape feedlot density map. Most of the feedlots identified are concentrated in the western half of the region.*

Land use change

Forest, wetlands, and shrubland-grassland

From 2015 to 2021, Western Cape saw a decrease in forest biomass, causing emissions to increase. This resulted in ~three million tonnes of CO_2e being released during this period. Biomass loss was notably higher in and around the Garden Route National Park region, located in the eastern part of the state.

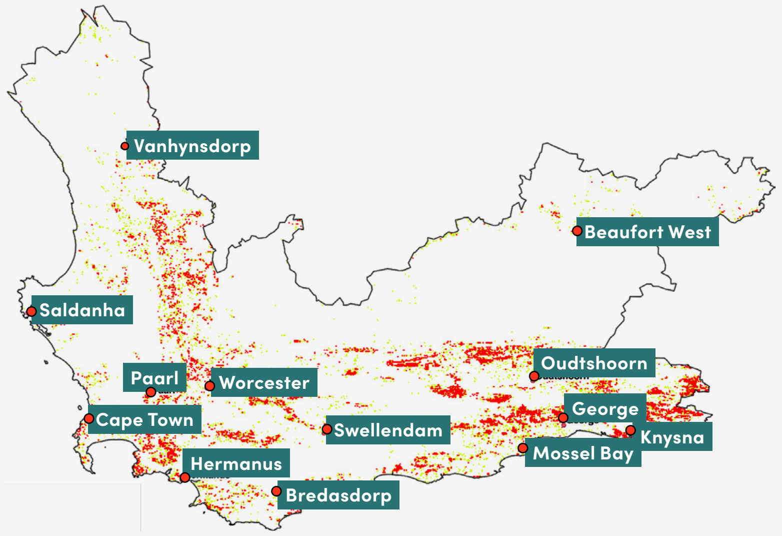
Figure 47



1 to 100 | >100

Figure 47: *Western Cape forest land biomass loss between 2015 and 2021. Legend value ranges from 1 to 100 (yellow) and >100 (red, largest emissions increase) tonnes of CO_2e.*

Figure 49

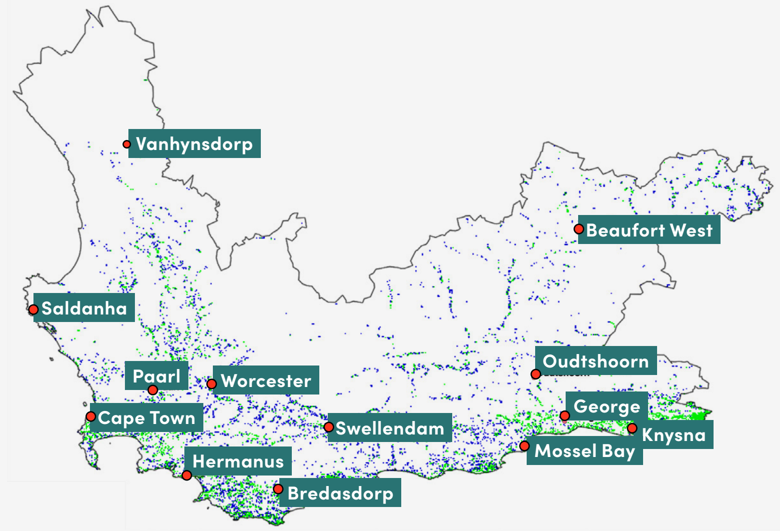


750 to 1500 | >1500

Figure 49: *Western Cape shrubland-grassland biomass loss between 2015 and 2021. Legend value ranges from 750 to 1,500 (yellow) and >1,500 (red, largest emissions increase) tonnes of CO_2e.*

However, shrubland-grassland biomass increased in Western Cape between 2015 and 2021. This resulted in the sequestration of 6.5 million tonnes of CO_2e.

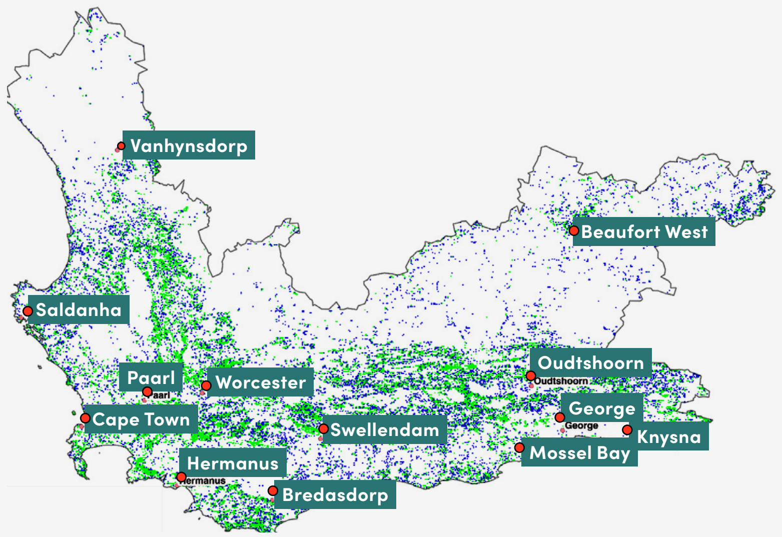
Figure 48



< -50 | -50 to -1

Figure 48: *Western Cape forest land biomass gain between 2015 and 2021. Legend value ranges from <-50 (green, largest emissions decrease) and -50 to -1 (blue) tonnes of CO_2e.*

Figure 50



< -1000 | -1000 to -500

Figure 50: *Western Cape shrubland-grassland biomass gain between 2015 and 2021. Legend value ranges from <-1,000 (green, largest emissions decrease) and -1,000 to -5000 (blue) tonnes of CO_2e.*

Future opportunities

The preliminary results from the STARRS pilot project show the immense value that detailed GHG emissions inventories have for subnational governments working to take climate action. Scaling this project to all states and regions, and eventually city governments, could unlock additional opportunities for climate mitigation at all levels of government. The project aims to solve a key barrier to decarbonisation — lack of access to granular and timely GHG data.

Although the project already provides GHG data for nearly all major emitting sectors, there are many opportunities for further improving the project over the coming years:

- Methodologies are being developed for further sectors and subsectors of data, particularly the buildings sector (heating, cooling, cooking); more waste subsectors (wastewater, biological treatment, burning); and industrial subsectors (chemicals, pulp, and paper).
- In addition, like all AI-based projects, the accuracy of the dataset will keep improving as more data are added. In fact, partnering with additional states and accessing their sample data and expertise helps improve the estimates for all regions and will help build acceptance for the dataset among other subnational governments.

The STARRS project dovetails with both Climate TRACE and Climate Group's broader goals: providing actionable GHG data to decision-makers and supporting subnational governments' climate commitments, respectively.

Climate Group is Secretariat of the Under2 Coalition, the largest global network of states, regions, provinces and other subnational governments committed to achieving net zero emissions by 2050, at the latest. It represents 167 individual states and regions along with several other national and subnational entities: a total of more than 270 actors, totalling more than 50% of global GDP. Knowledge sharing and peer learning is a core part of its work. Using the strength of its network, the Under2 Coalition will connect other states and regions with this approach and push for greater transparency and accountability in emissions monitoring and action.

Climate TRACE aims to bolster transparency in emissions tracking through its comprehensive, independent global inventory of nearly all major sources of emissions worldwide — which will eventually include every large individual source of emissions like power plants, factories, or ships. Climate TRACE currently provides annual emissions data for every country and most territories around the world from 2015-2021, as well as data for more than 70,000 of the largest individual sources of emissions. This inventory will expand to include additional sources and provide even more timely data.

Figure 52: Climate TRACE roadmap

2021 — Country-level launch
- Major emitting sectors for all countries (2015-2020)

2022 — Asset level launch
- Annual asset-level estimates for largest emitting sources
- Metadata on location, type, capacity, etc
- 2021 country data

2023 — Complete asset level
- Annual asset-level estimates for all major emitting sources globally
- Detailed metadata

2024 — Monthly reporting
- Asset-level estimates for major emitting sources worldwide, most weekly or monthly level, with detailed metadata

References

1 NewClimate Institute, Data-Driven EnviroLab, Utrecht University, German Development Institute/Deutsches Institut für Entwicklungspolitik (DIE), CDP, Blavatnik School of Government, University of Oxford (2021) Global climate action from cities, regions and businesses: www.newclimate.org/resources/publications/global-climate-action-from-cities-regions-and-businesses-2021

2 Climate Group (2020) Annual Disclosure Report: www.theclimate group.org/Annual Disclosure2020

3 Climate Group (2022): STARRS COP27 side event: Multilevel action & the amambition loop: implementing the Glasgow Climate Pact to keep 1.5 alive: https://unfccc.int/event/tcg-united-kingdom-of-great-britain-and-northern-ireland-multilevel-action-the-ambition-loop

4 Global Covenant of Mayors (2023): www.globalcovenantofmayors.org Disclosure2020

5 Environmental Justice Atlas (2021) Oil drilling project Ombrina Mare, Abruzzo, Italy: https://ejatlas.org/conflict/estrazione-di-idrocarburi-ombrina-mare

6 Government of The Basque Country (2015) Climate Change Strategy of the Basque Country 2050: https://www.euskadi.eus/contenidos/documentacion/klima2050/en_def/adjuntos/KLIMA2050_en.pdf

7 European Commission (2022) EU Emissions Trading System (EU ETS): https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en

8 Climate Group (2023) Climate Footprint Project: https://www.theclimategroup.org/climate-footprint-project

9 Government of Pernambuco (2022) Paulo câmara lança plano de descarbonização de Pernambuco: www.pe.gov.br/blog/tecnologia/520-paulo-camara-lanca-plano-de-descarbonizacao-de-pernambuco

10 Climate Group (2023) Climate Footprint Project: Phase I: www.theclimate group.org/climate-footprint-project-phase-i

11 Data México (2022) Querétaro: www.datamexico.org/en/profile/geo/queretaro-qt

11 Climate Group (2022) Development and evaluation of Querétaro's decarbonisation pathway: https://www.theclimategroup.org/our-work/resources/development-and-evaluation-queretaros-decarbonisation-pathway

Acknowledgements:

We'd like to thank the following state government representatives for their support and participation in the STARRS project:

Aideé Morales
Alejandra Aguilar Ramirez
Ana Ortega
Arturo Palero
Carlos Castillo
Chiara Barchiesi
Gemma Perez
Gerard van Weele
Ivson Santana
Jody Brown
Karla Elizalde
Lize Jennings-Boom
Márcio Erlich
Miguel Leon
Ricardo Javier Torres Hernández
Samanta Della Bella
Stefania Perna
Wendy Erika Martínez Reséndiz

Funding:

We're grateful for the support of ClimateWorks Foundation and Google.org.

Report content:

Aaron Davitt
Anaísa Pinto
Gabriela Volpato
Hannah Davies
Lee Gans
Lekha Sridhar

Project team:

Anaísa Pinto
Aaron Davitt
Emmy van Enk
Gabriela Volpato
Hannah Davies
Jebi Rahman
Lee Gans
Lekha Sridhar
Monica Mata
Natalie Orentlicher
Roisin Gorman
Rolf Bateman
Sophie Benger
Thyla-Jay Quickfall

Report editing:

Fae Jencks
Nikki Arnone
Peter Bronski

Report design:

Alchemy Mill
www.alchemymill.co.uk

CLIMATE GROUP

Climate Group is an international non-profit founded in 2003, with offices in London, New York, New Delhi, Amsterdam and Beijing.

Our mission is to drive climate action, fast.

Our goal is a world of net zero carbon emissions by 2050, with greater prosperity for all. We do this by forming powerful networks of business and government, unlocking the power of collective action to move whole systems such as energy, transport, the built environment, industry, and food to a cleaner future. Together, we're helping to shift global markets and policies towards faster reductions in carbon emissions.

For more information, please visit: www.theclimategroup.org

CLIMATE TRACE

Climate TRACE (Tracking Real-time Atmospheric Carbon Emissions) is a global coalition of nonprofits, tech companies, and universities created to make meaningful climate action faster and easier by independently tracking greenhouse gas (GHG) emissions with unprecedented detail and speed. Climate TRACE harnesses satellite imagery and other forms of remote sensing, artificial intelligence, and data science expertise to identify human-caused GHG emissions when and where they happen.

Coalition members include Blue Sky Analytics, Carbon Yield, Earthrise Alliance, Hypervine, Johns Hopkins University Applied Physics Laboratory, OceanMind, RMI, TransitionZero, WattTime, and climate leader and former U.S. Vice President Al Gore. In addition, over 90 other organisations and researchers have contributed to the work including: CTREES, Global Energy Monitor, Michigan State University, Minderoo Foundation/Global Plastic Watch, Planet Labs PBC, Synthetaic, GHGSat, Universiti Malaysia Terengganu, and others.

For more information, please visit: climatetrace.org

The Climate Change Organisation (The Climate Group) with Company Registration Number: 4964424 and Charity Registration Number: 1102909
The Climate Group, Inc. is a U.S. registered 501(c)3 with EIN 43-2073566
M/s TCCO India Projects Private Limited with Corporate Identity Number U74999DL2018PT