



Emission Inventory Development and Projections for the Transforming Mexican Energy Sector

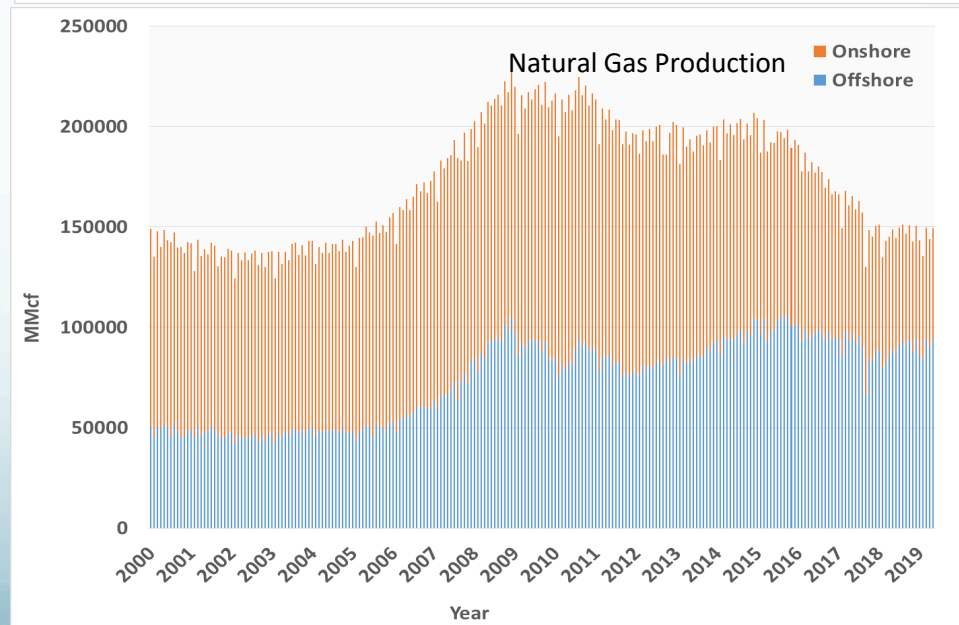
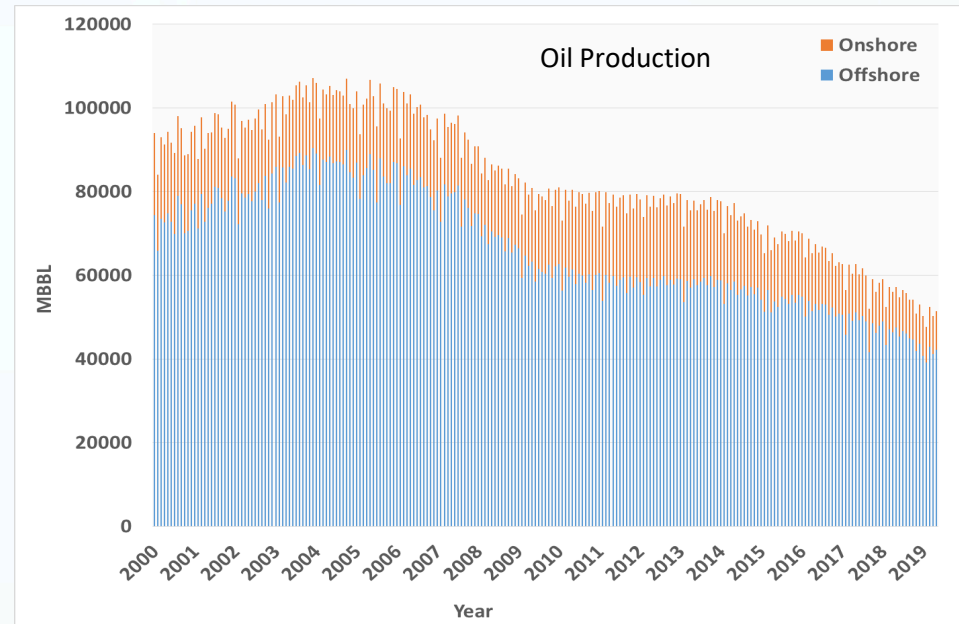
Gary McGaughey and Elena McDonald-Buller
Center for Energy and Environmental Resources
The University of Texas at Austin

John Grant, Tejas Shah, and Greg Yarwood
Ramboll
Novato, California

AQRP Project 19-023
Texas Air Quality Research Program Workshop
August 22, 2019

Background

- Long history of oil production central to Mexican economy
- Exporter of crude oil but importer of refined petroleum products, coal, and natural gas
- Energy sector challenged by declining oil and natural gas production revenues, lack of investment resources, rising electricity demand*



* Source: IEA, 2018

Transformational Changes

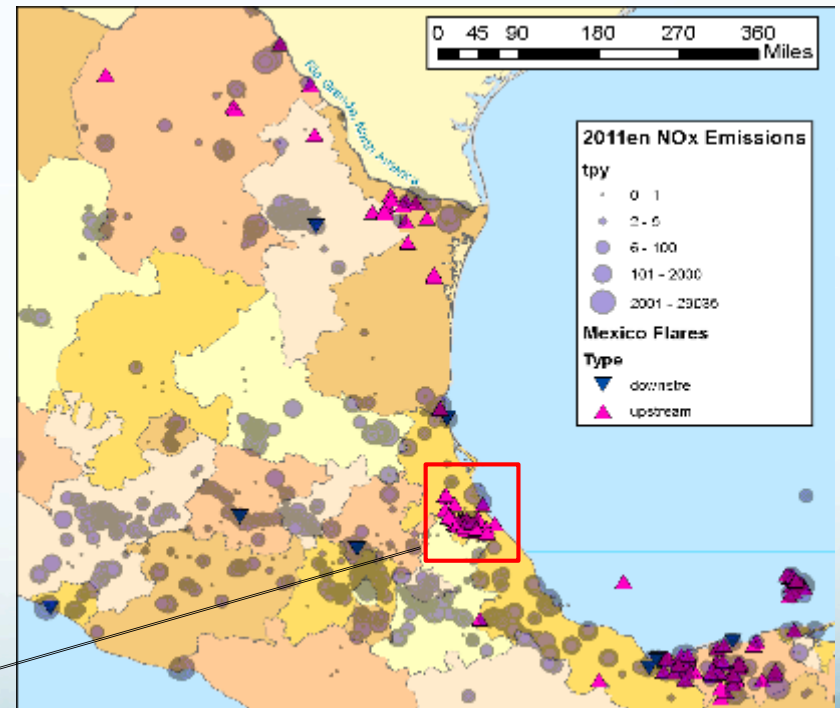
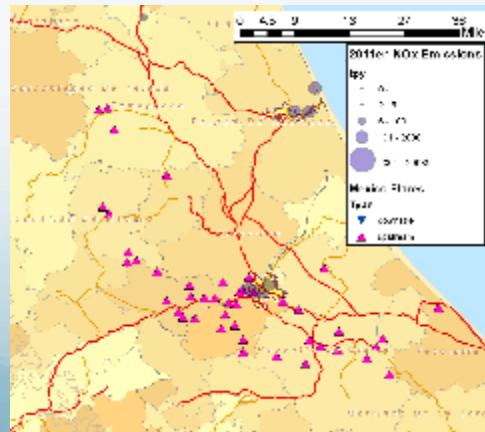
- Energy reform part of *Pacto Por Mexico* under Peña-Nieto
- Ratification of amendments to Mexican Constitution adopted in December 2013 with secondary legislation in August 2014
- Encourages domestic and foreign investment and productivity growth in oil, gas and power sectors
- Ends state-owned monopolies of Petróleos Mexicanos (Pemex) and Comisión Federal de Electricidad (CFE)

Rondas Mexico

- Bid rounds (*Rondas Mexico*) initiated in 2015
- Attract investment for exploration/extraction of onshore and offshore oil and gas resources
- Potential to transform emissions over the next one to two decades

Top-Down Assessment of Upstream Oil and Gas Sector

- Parker and Shah (2018) compared VIIRS-derived gas flaring estimates* for oil and gas production areas to EPA's 2011en inventory.
- Downstream flares included in EPA inventory but most upstream flares were missing



*https://www.ngdc.noaa.gov/eog/viirs/download_global_flare.html

Project Objectives

- Develop a **bottom-up emissions estimates** for **upstream** (onshore and offshore oil and gas drilling and producing well sites; flaring) and **midstream** sector sources (natural gas compressor stations and natural gas processing plants) and **electric generating units** in Mexico for the 2016 base year
- Track hydrocarbon bid rounds, **map awarded contractual areas** relative to active onshore well locations in 2016, and conduct a speculative assessment of emissions that could accompany ongoing development

This project addressed the TCEQ's research priority to develop significant improvements in emissions inventories for Mexico, Central America, and the Caribbean, including both terrestrial and offshore emissions

Upstream Oil and Natural Gas EI

- **Onshore Wells (9809 active wells)**
 - EI includes exploration (drilling, hydraulic fracturing, and completion) and production (fugitive leaks, pneumatic controllers and pumps, wellhead engines such as compressor engine and artificial lift engines, oil and condensate tanks, and liquid unloading/well venting sources)
- **Offshore Platforms (Shallow Water < 500 feet; 649 active wells)**
 - EI includes exploration (drilling) and production (fugitive leaks, engines, turbines, boilers, and flares).
 - No estimates for non-platform emissions (e.g., marine vessels, pipelaying, support helicopters)

Upstream EI Resources

- **CNIH**

- Production and well descriptive data obtained from Mexico's National Hydrocarbons Information Center (CNIH) of the National Hydrocarbons Commission (CNH)

- **EPA**

- Onshore emissions estimates employed 2014 NEIv2 and EPA NEI O&G Tool to develop surrogate activity and emissions rates for Mexico upstream well sites

- **BOEM (Wilson et al., 2017)**

- Offshore emissions from Mexican oil/gas platforms developed from an analysis of US offshore (Outer Continental Shelf) oil and gas emissions under the jurisdiction of the Bureau of Ocean Energy Management (BOEM) for calendar year 2014

CNIH Oil and Gas Data Portal (https://sih.hidrocarburos.gob.mx/)

Mapa de series
y descargas



Descargar
todo



Sección
Tema

Periodicidad

Anual
 Mensual
 Diario

Fecha

Inicio:
Fin:

PRODUCCION DE PETROLEO Y GAS POR CUENCA Y UBICACION

Buscar:

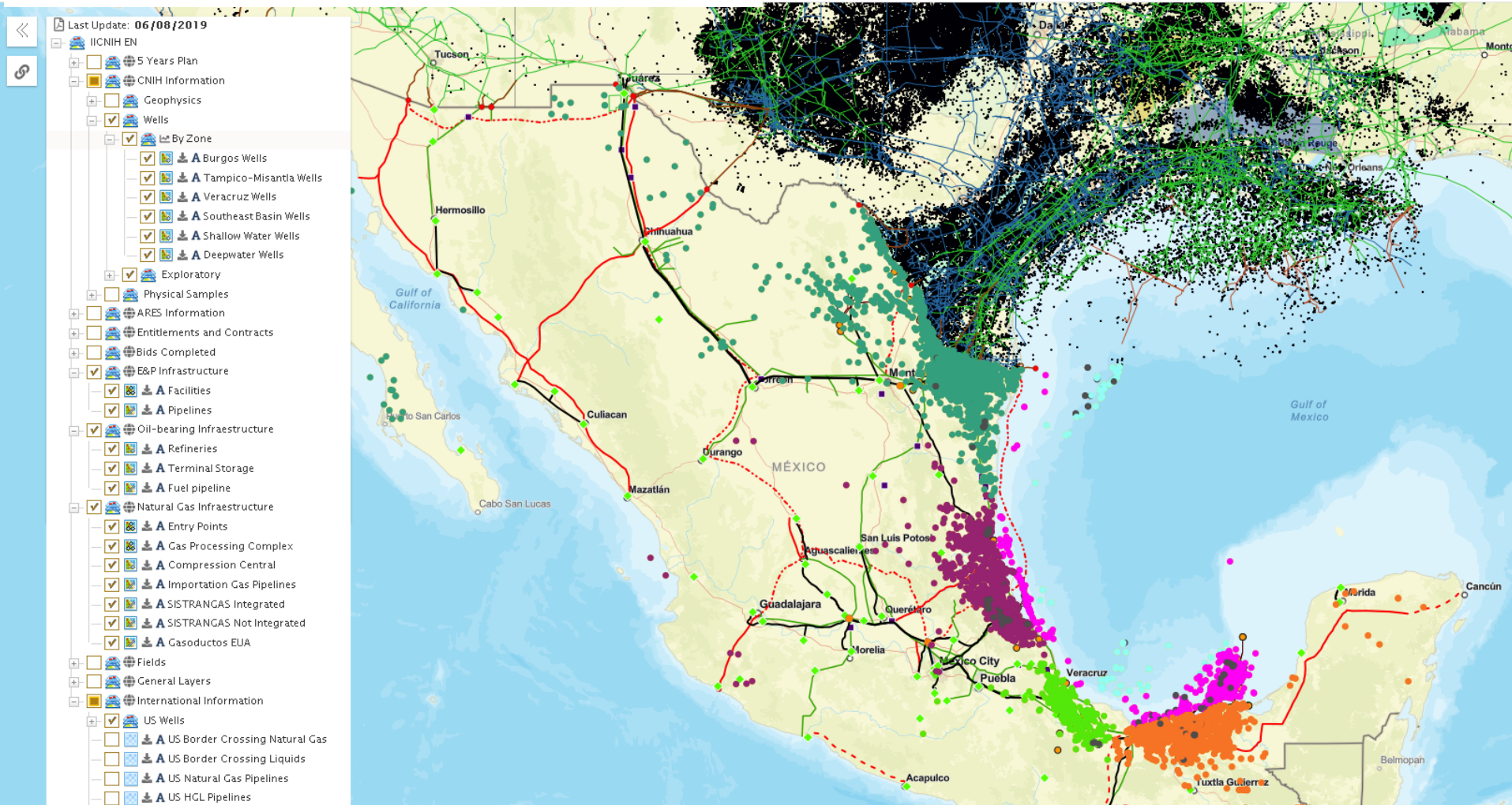
- + BURGOS
- + CINTURON PLEGADO DE CHIAPAS
- CUENCAS DEL SURESTE
- PRODUCCIÓN

			2018/Ago	2018/Sep	2018/Oct	2018/Nov	2018/Dic	2019/Ene	2019/Feb	2019/Mar	2019/Abr	2019/May	2019/Jun
		Descargar selección											
Petróleo (Mbd)		<input type="checkbox"/>	1,706.9	1,718.6	1,657.0	1,609.2	1,619.3	1,533.9	1,611.8	1,600.3	1,583.9	1,570.1	1,577.3
Aguas someras		<input type="checkbox"/>	1,480.3	1,494.0	1,435.0	1,392.4	1,401.2	1,312.8	1,394.9	1,382.8	1,366.7	1,354.7	1,362.2
Terrestre		<input type="checkbox"/>	226.6	224.6	221.9	216.8	218.2	221.1	216.9	217.5	217.2	215.4	215.1
Gas (MMpcpd)		<input type="checkbox"/>	3,861.1	3,877.8	3,849.1	3,733.2	3,835.5	3,624.8	3,844.4	3,832.3	3,810.4	3,829.6	3,816.2
Aguas someras		<input type="checkbox"/>	2,988.6	3,020.6	2,995.1	2,898.7	2,999.0	2,759.8	2,976.9	2,993.0	2,988.9	3,014.5	3,003.7
Terrestre		<input type="checkbox"/>	872.5	857.2	854.0	834.5	836.5	865.0	867.5	839.3	821.5	815.1	812.4
Gas asociado (MMpcpd)		<input type="checkbox"/>	3,654.3	3,674.0	3,645.9	3,536.1	3,650.6	3,430.1	3,644.2	3,639.4	3,609.6	3,624.3	3,617.2
Aguas someras		<input type="checkbox"/>	2,868.6	2,901.9	2,873.1	2,777.4	2,877.9	2,635.3	2,852.7	2,869.3	2,857.3	2,877.9	2,873.0
Terrestre		<input type="checkbox"/>	785.7	772.0	772.8	758.7	772.7	794.7	791.5	770.1	752.3	746.4	744.2
Gas no asociado (MMpcpd)		<input type="checkbox"/>	206.8	203.8	203.2	197.2	184.9	194.7	200.1	192.9	200.8	205.3	199.0
Aguas someras		<input type="checkbox"/>	120.0	118.6	121.9	121.3	121.1	124.4	124.2	123.7	131.6	136.5	130.7
Terrestre		<input type="checkbox"/>	86.8	85.2	81.2	75.9	63.8	70.3	75.9	69.2	69.2	68.7	68.3
Nitrógeno (MMpcpd)		<input type="checkbox"/>	1,200.3	1,169.8	1,173.1	1,097.3	1,167.5	1,029.2	1,110.0	1,126.5	1,051.8	996.3	1,063.6
Aguas someras		<input type="checkbox"/>	1,079.4	1,051.6	1,056.1	982.3	1,055.0	917.9	1,001.0	1,019.5	945.3	890.2	956.9
Terrestre		<input type="checkbox"/>	120.9	118.1	117.0	114.9	112.6	111.3	109.0	107.0	106.5	106.1	106.7
Condensado (Mbd)		<input type="checkbox"/>	18.0	16.8	17.2	16.7	15.4	15.7	17.4	16.2	15.9	16.6	17.5
Aguas someras		<input type="checkbox"/>	15.6	14.8	14.9	14.1	12.8	13.1	14.6	13.4	12.9	13.9	14.9
Terrestre		<input type="checkbox"/>	2.4	2.0	2.3	2.6	2.5	2.6	2.8	2.9	3.0	2.7	2.6

- + SABINAS
- + TAMPICO-MISANTLA
- + VERACRUZ

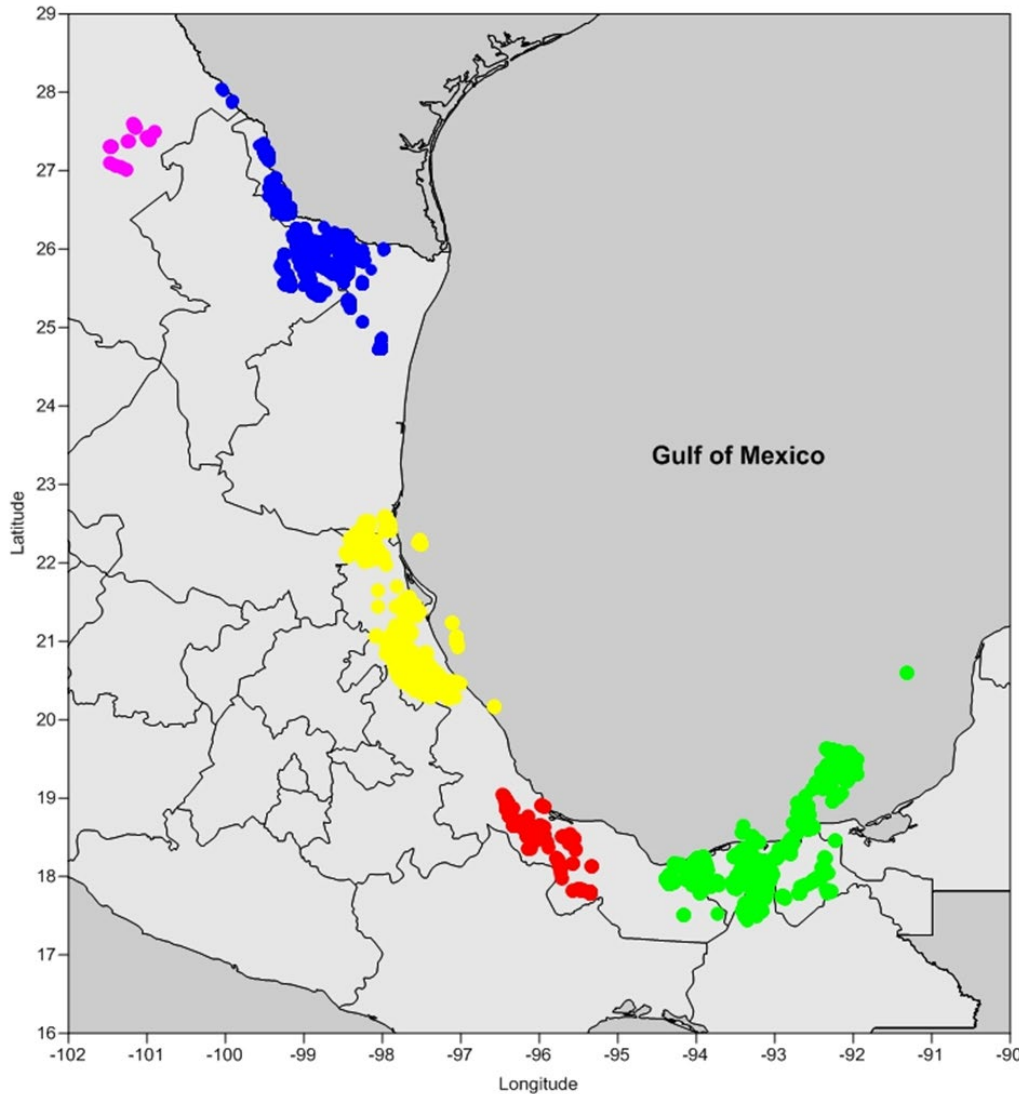
CNIH Oil and Gas GIS Portal (<https://mapa.hidrocarburos.gob.mx/>)

US wells in black, Mexico in other colors



GIS Layers include: Mexican Exploration and Production, Mexican Oil and Natural Gas Infrastructures, US Wells and Natural Gas Pipelines

Active well locations during 2016



Numbers of Onshore Wells

Burgos: 3273 gas

Sabinas: 26 gas

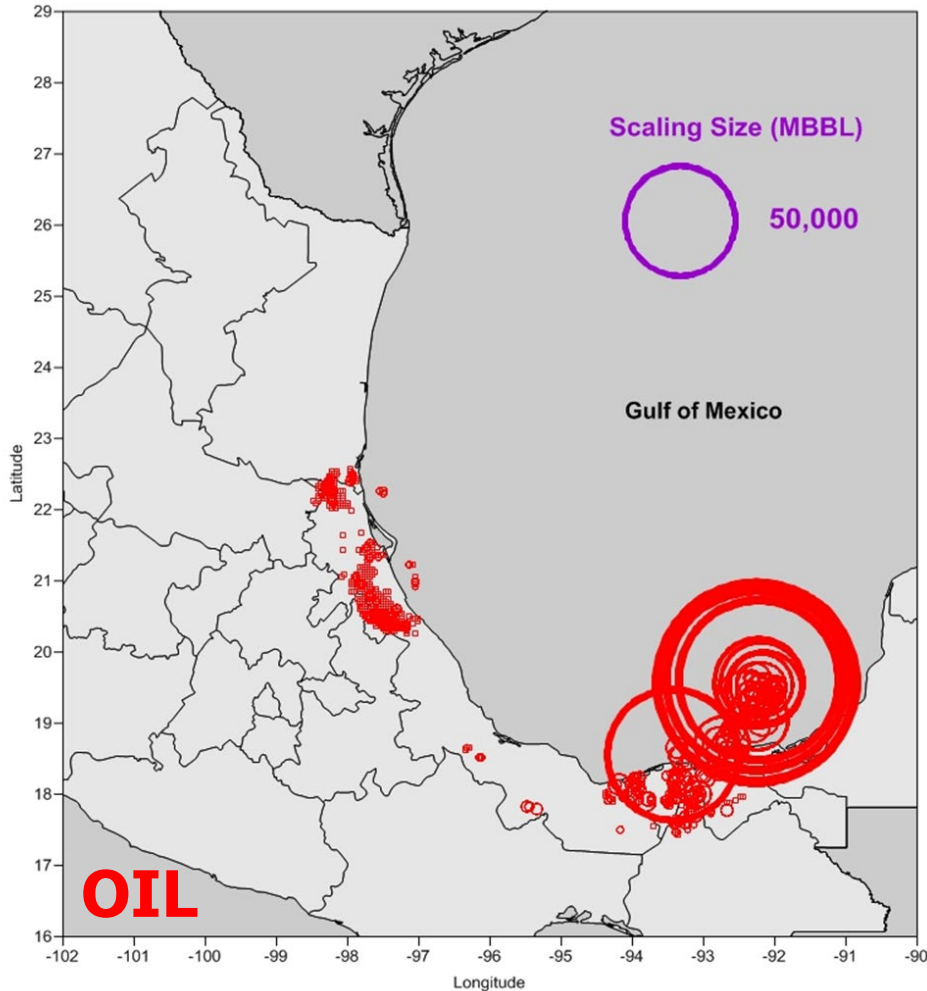
Sureste: 278 gas; 1256 oil

Tampico-Misantla: 634 gas;
4074 oil

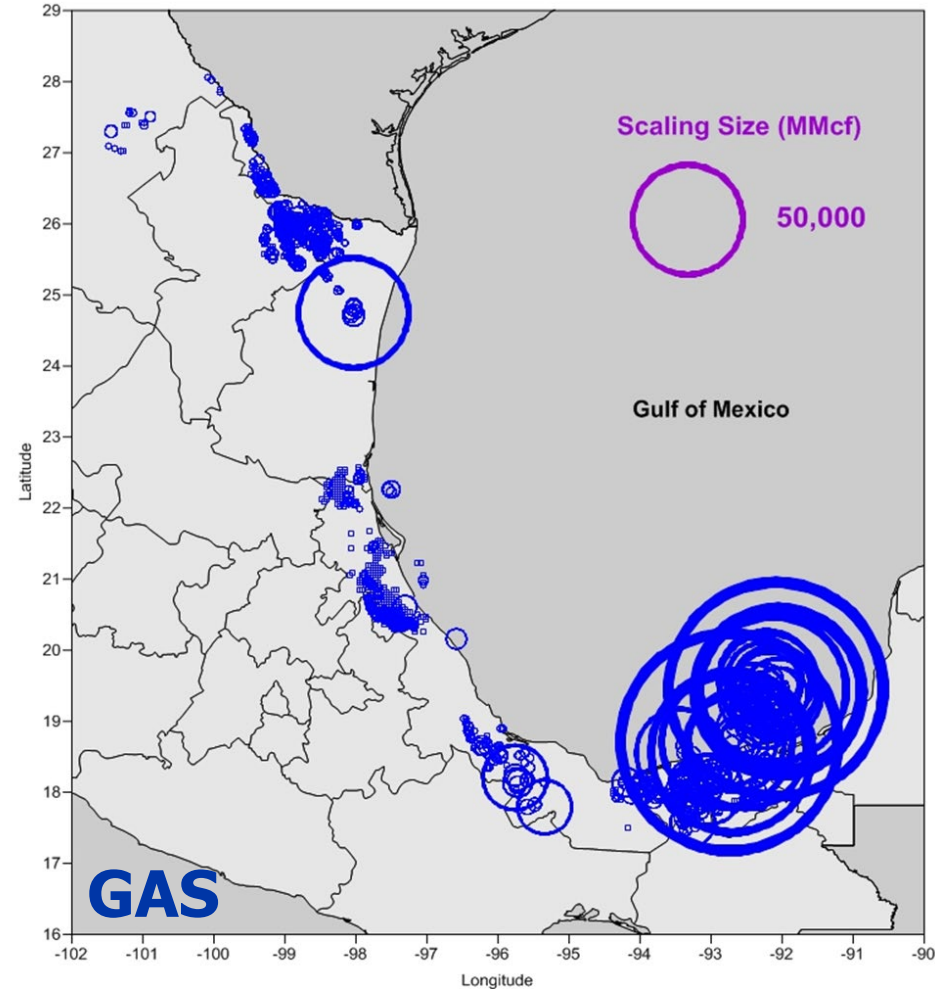
Veracruz: 218 gas; 50 oil

Offshore: ~100% Oil Wells

Production: Oil (left, MBBL) and Gas (right, MMCF)



Total oil production: 788,738 MBBL
Onshore: 163,598
Offshore: 625,141
Sureste: 16% (onshore); 79% (offshore)



Total gas production: 2,127,142 MMCF
Onshore: 1,155,446
Offshore: 971,696
Sureste: 22% (onshore); 54% (offshore)

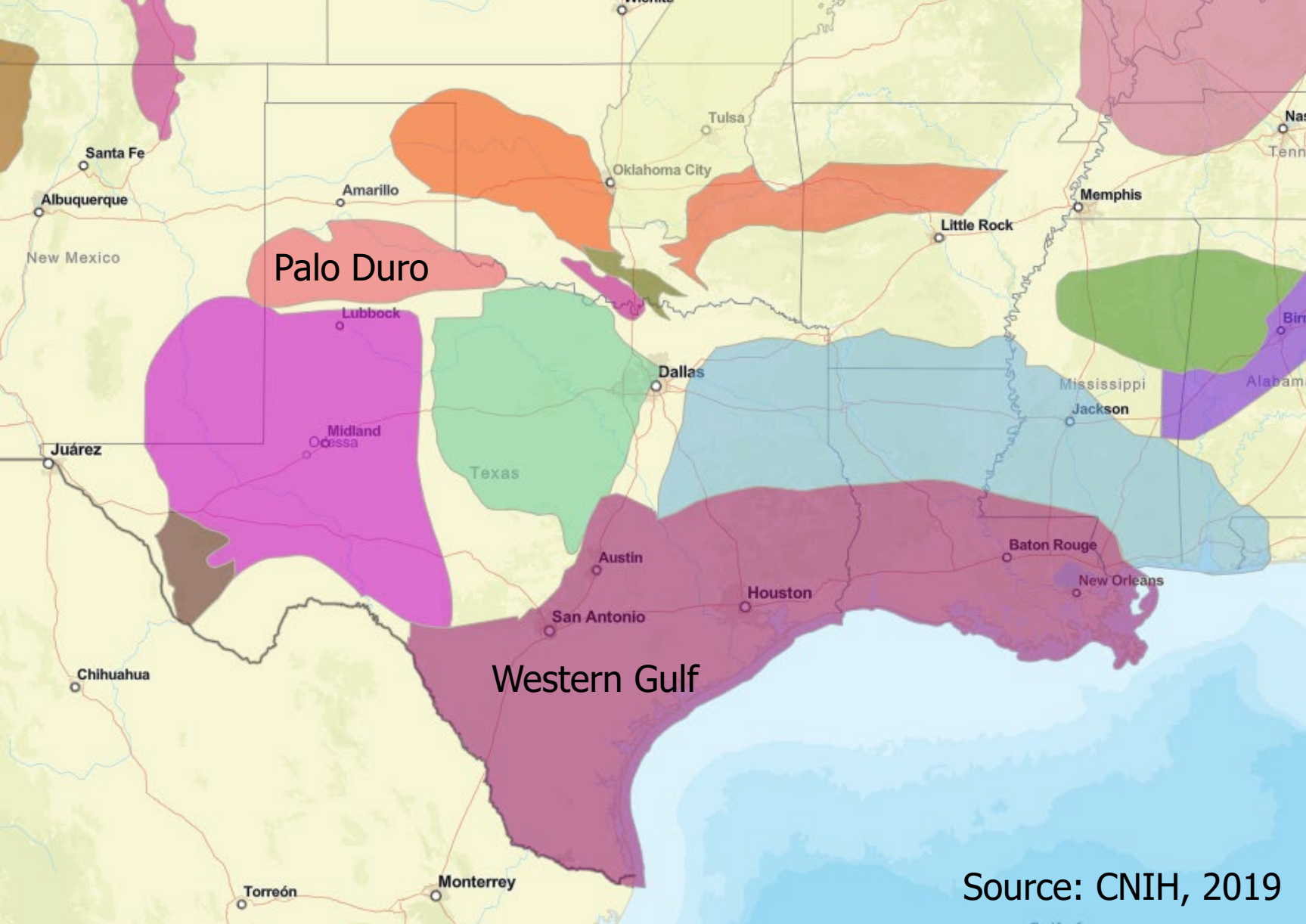
Upstream Oil and Natural Gas EI Methodology

- Activity surrogates include production volumes, active well count, spud count
- Mexican O&G production during 2016 consists primarily of vertical legacy wells
- Because well site equipment configuration data were not readily available, emission rates were based on representative Texas basins normalized to the appropriate activity surrogate and then adjusted to reflect expected minimal emissions controls in Mexico

Upstream Oil and Natural Gas US Emissions Surrogates

- Onshore Sabinas/Burgos
 - Western Gulf Basin (Texas)
 - Geographically contiguous basins across Texas-Mexico border
 - Removed Texas specific controls and condensate related emission sources
- Onshore Sureste, Tampico-Misantla, and Veracruz
 - Palo Duro Basin (Texas)
 - Declining production from vertical wells with limited exploration activity similar to Mexico basins
 - Removed Texas specific controls
- Offshore BOEM (2014 data) Platforms
 - For consistency with Mexico offshore platforms, (1) limited to platforms in <500 feet of water and (2) limited to Mexico platform gas-to-oil ratio (GOR) range of 0 to 130 mcf/bbl
- Flaring
 - Basis is circa-2012 Shah et al. (2018) estimates, with adjustments to account for activity changes for 2016

Texas Basins



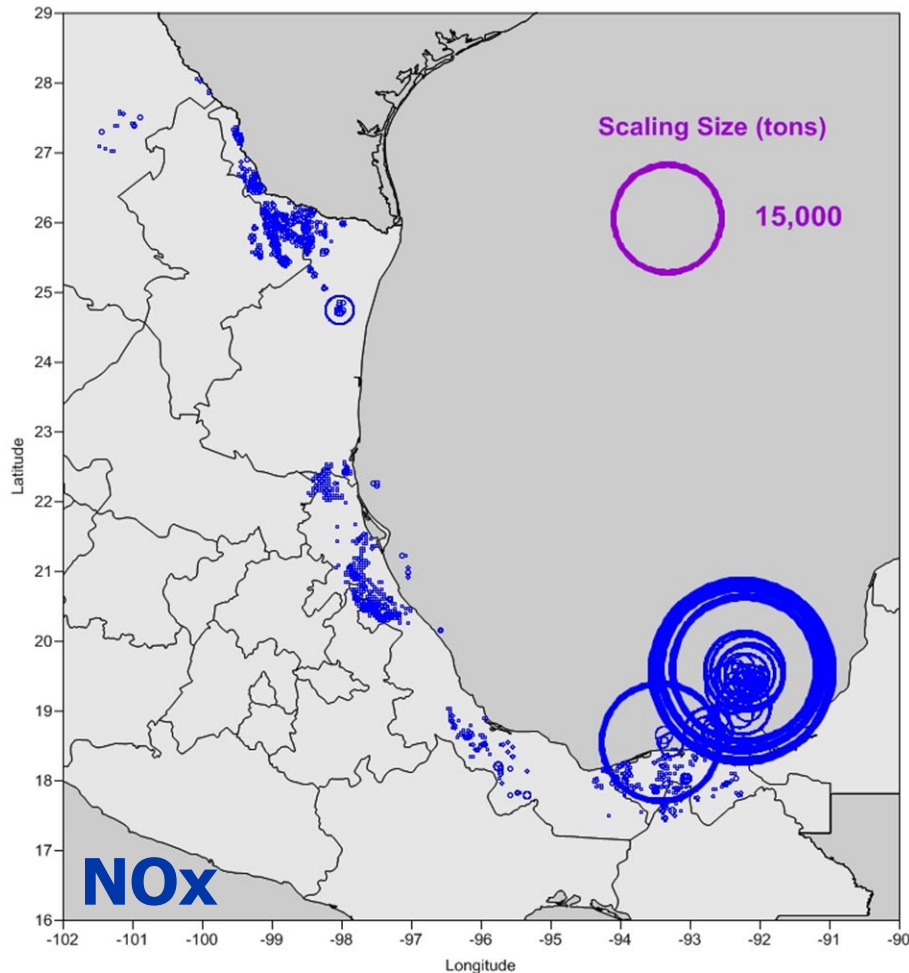
Source: CNIH, 2019

Upstream 2016 Annual Emissions Results (tons)

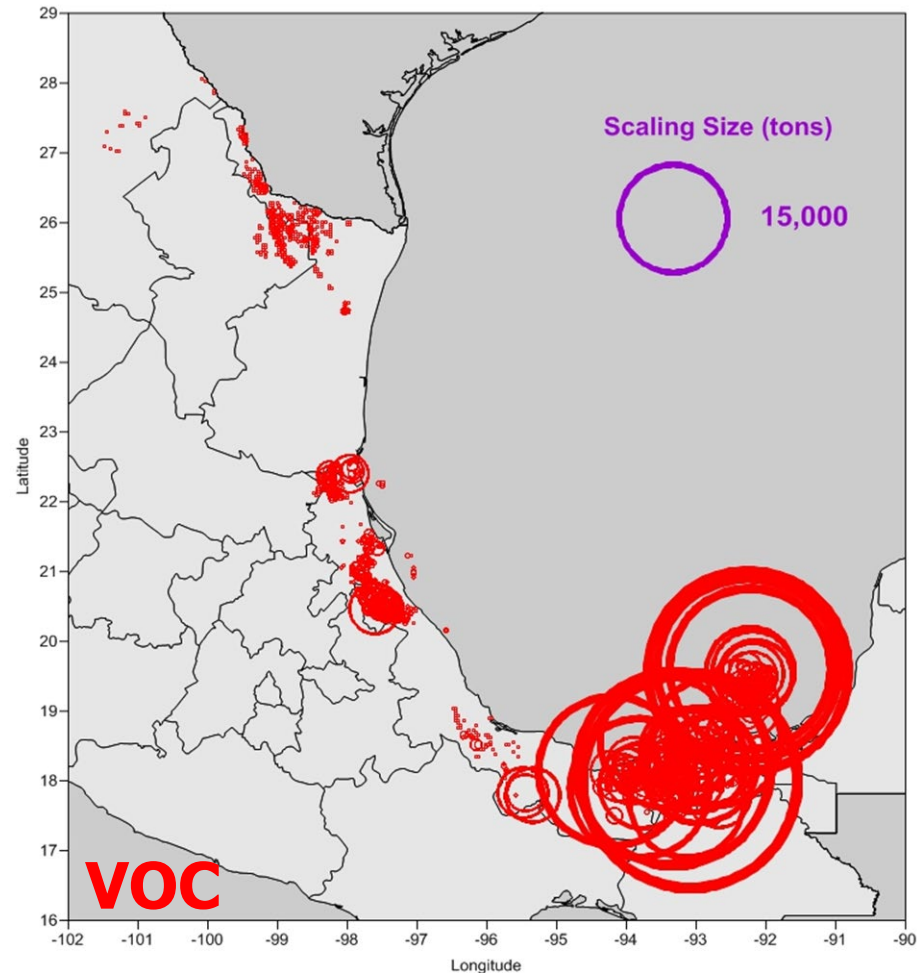
Basin	NO _x	CO	SO ₂	VOC	PM _{2.5}	PM ₁₀	NH ₃
Veracruz	3839	1188	4	21176	21	22	
Tampico-Misantla	6125	7592	53	131,955	122	124	0.2
Burgos/Sabinas	27,860	8383	4	5234	93	93	
Sureste	239,947	285,557	1764	686,020	3309	3316	38.4
Total	277,771	302,720	1825	844,385	3546	3555	38.6

*NH3 not estimated for onshore wells.

2016 Annual NOx (left) and VOC (right); Units: tons



Total: 277,771 tons
Onshore: 56,898 tons
Offshore: 230,872 tons
Sureste: 4% (onshore); 83% (offshore)



Total: 844,385 tons
Onshore: 586,491 tons
Offshore: 257,894 tons
Sureste: 51% (onshore); 30% (offshore)

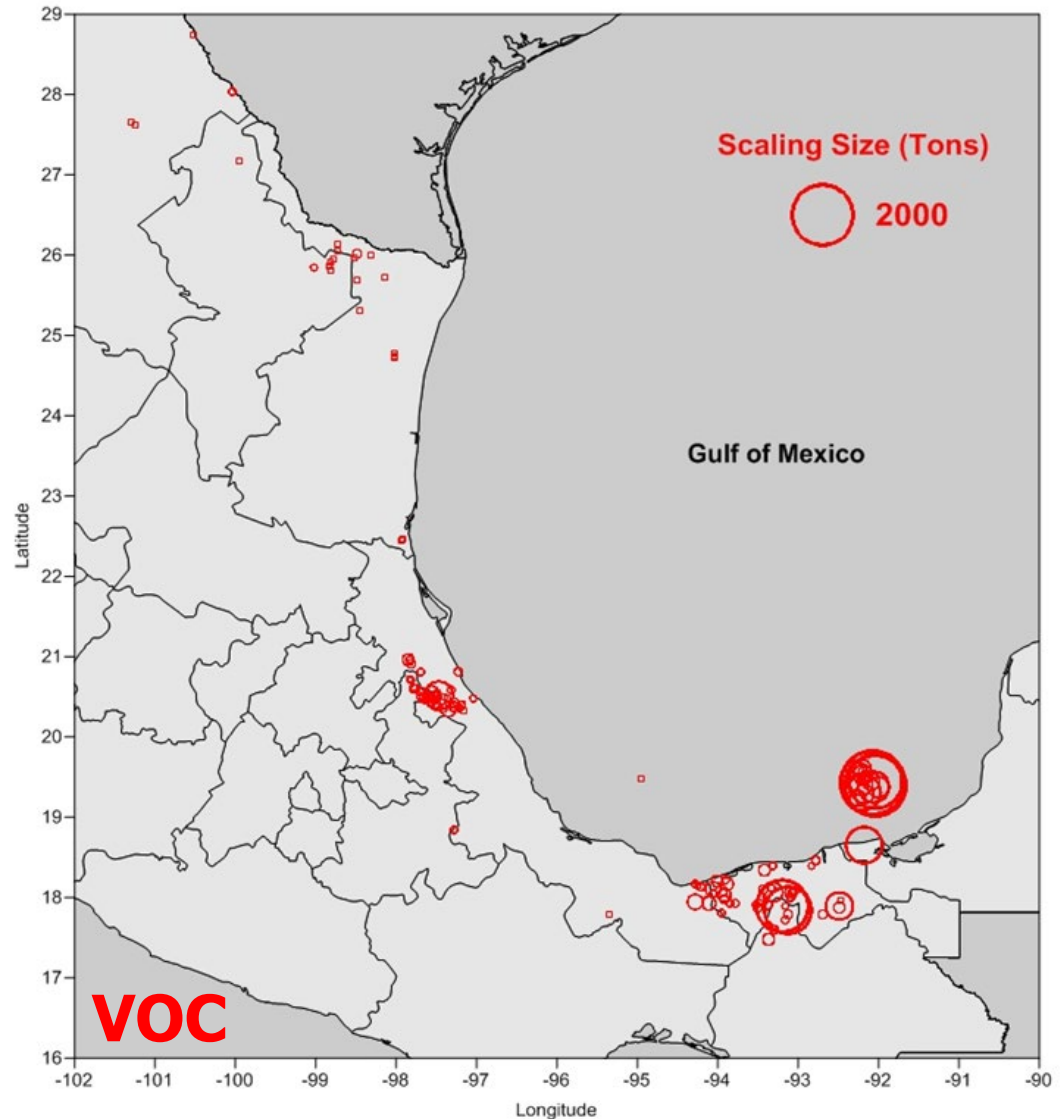
Well Site Flaring

Shaw et al. (2018) estimates for 2012 based on Visible Infrared Imaging Radiometer Suite (VIIRS) and AP-42 and EPA NEI O&G Tool

Ratioed to 2016 using by basin onshore/offshore gas production volumes between 2012 and 2016

TPY

NO_x: 6,579
VOC: 23,005
CO: 30,073
SO₂: 72,666



Midstream Gas Processing Plants and Compressors

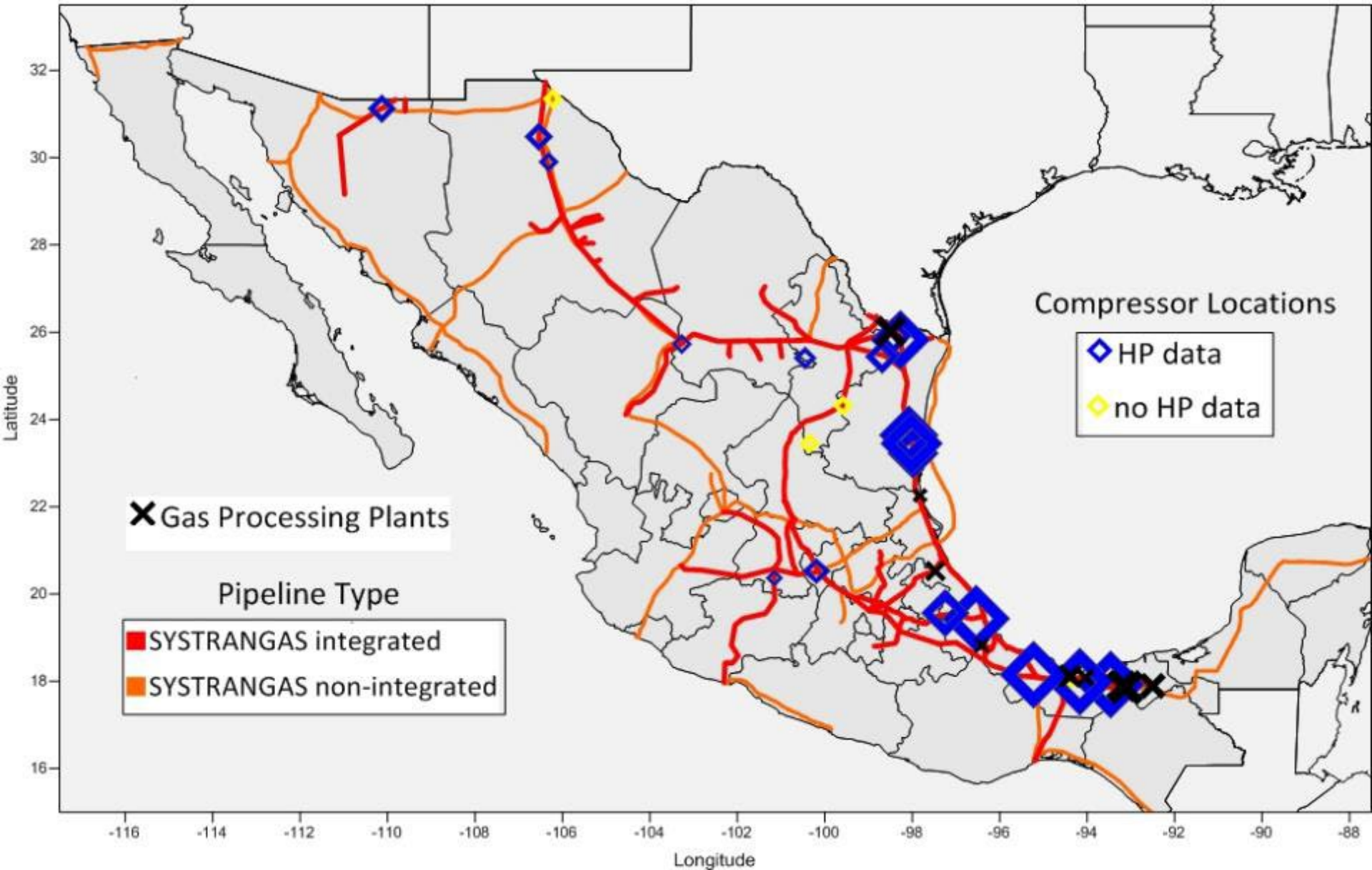
- **Gas Processing Plants (11)**

- For 8 plants, EI based on the 2008 Mexico National Emissions Inventory (Inventario Nacional de Emisiones de México or INEM) ratioed by 2016 to 2008 natural gas intake volumes
- For the 3 remaining (nonINEM) facilities, EI estimated using by-pollutant linear regression between emissions and production

- **Natural Gas Compressor Stations (22)**

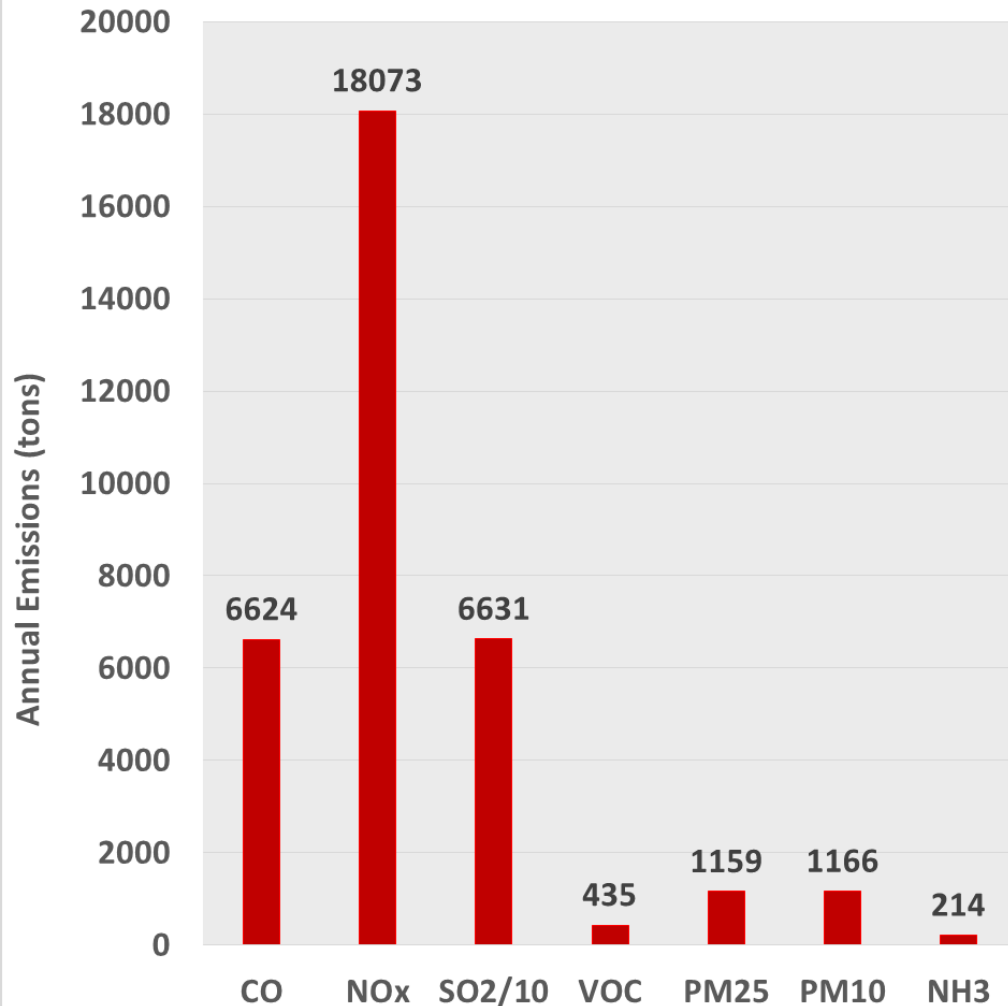
- Employed AP-42 emission factors for uncontrolled 4-stroke rich burn engines and facility-specific installed horsepower
- Conservatively assumed full load and 8764 hours of operation

Gas Processing Plant and Compressor Station Locations

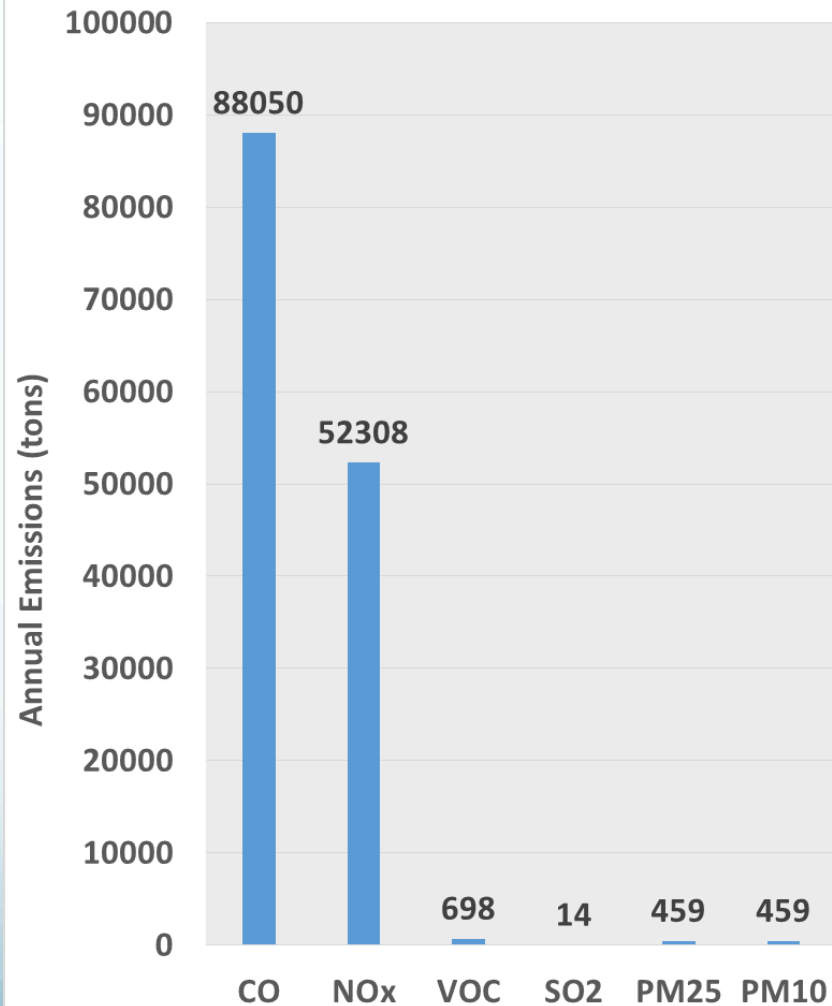


2016 Annual Gas Processing and Compressor Emissions

GAS PROCESSING PLANTS



COMPRESSORS



EGU EI Datasets

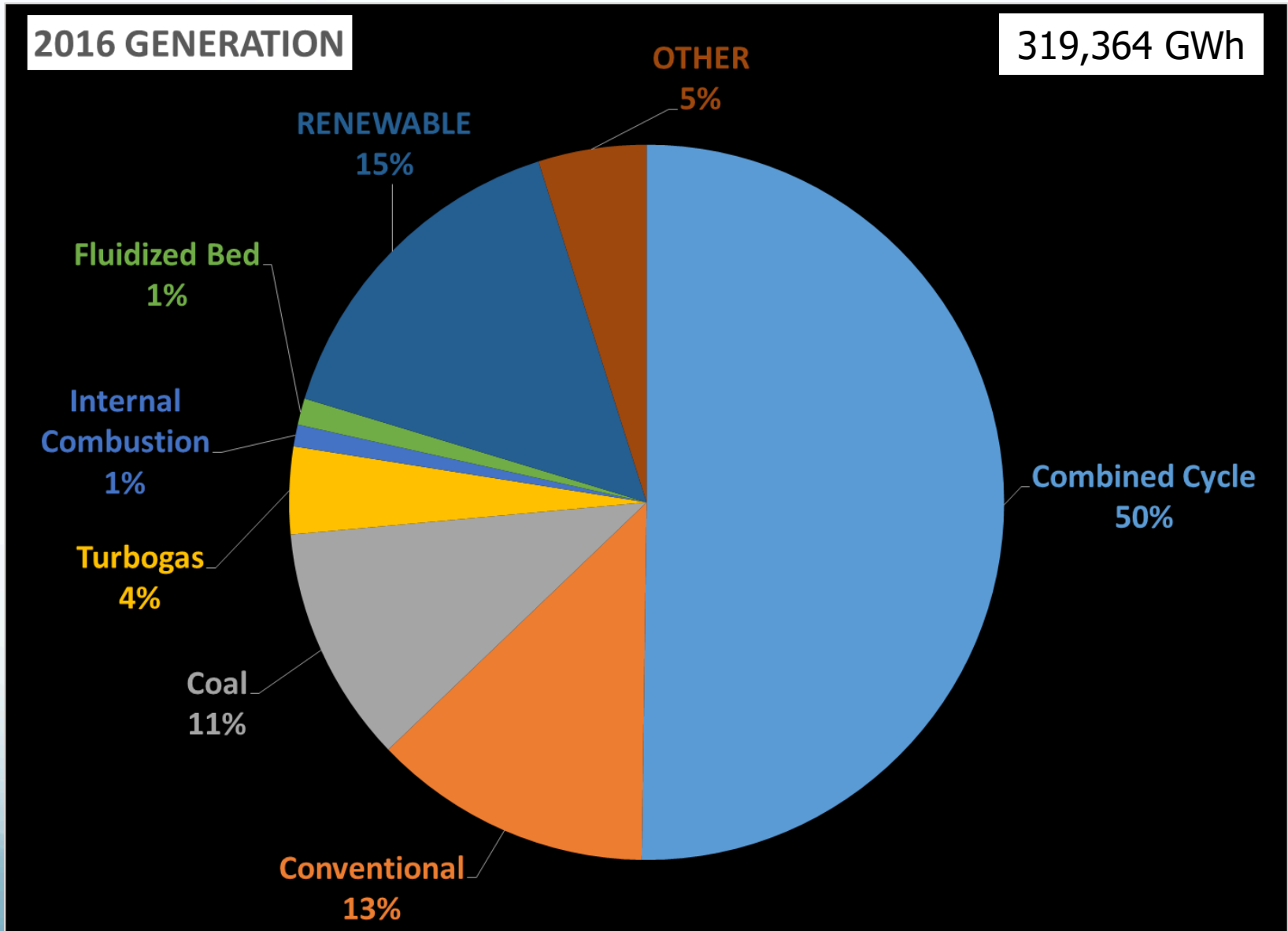
- **PRODESEN (2017)**

- Mexico's Ministry of Energy (SENER) issues the annual planning document, the National Electricity System Development Program or PRODESEN regarding generation, transmission, and distribution of electricity. Each annual report includes existing electricity generation and capacity at the facility level for both thermal and renewable resources

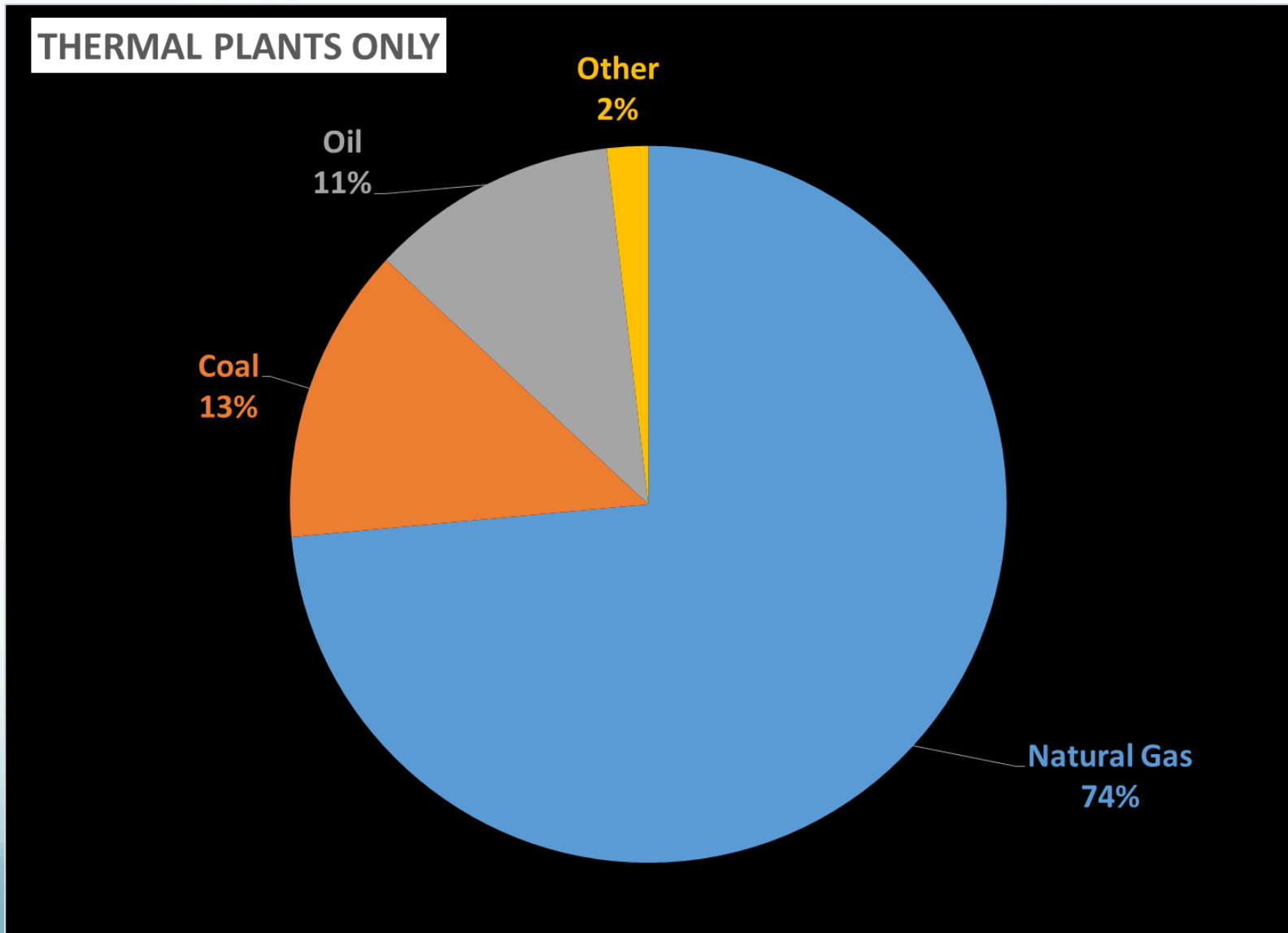
- **COPAR (2015)**

- Mexico's Federal Electricity Commission (CFE) periodically publishes Costos y Parametros de Referencia or COPAR reports that are used by the Mexican government to establish the relative differences in projected costs of electricity generation by fuel and technology but also contain publicly available information on facility-specific emissions

2016 Electricity Generation by Technology (left)



2016 Electricity Generation by Fuel



2016 Generation by Fuel (Thermal Plants Only)

Numbers of
Facilities (355 Total)

Coal: 3

Diesel (113)

IC: 92

TG: 21

Gas (208)

Cogen: 20

CC: 67

Conv: 24

IC: 39

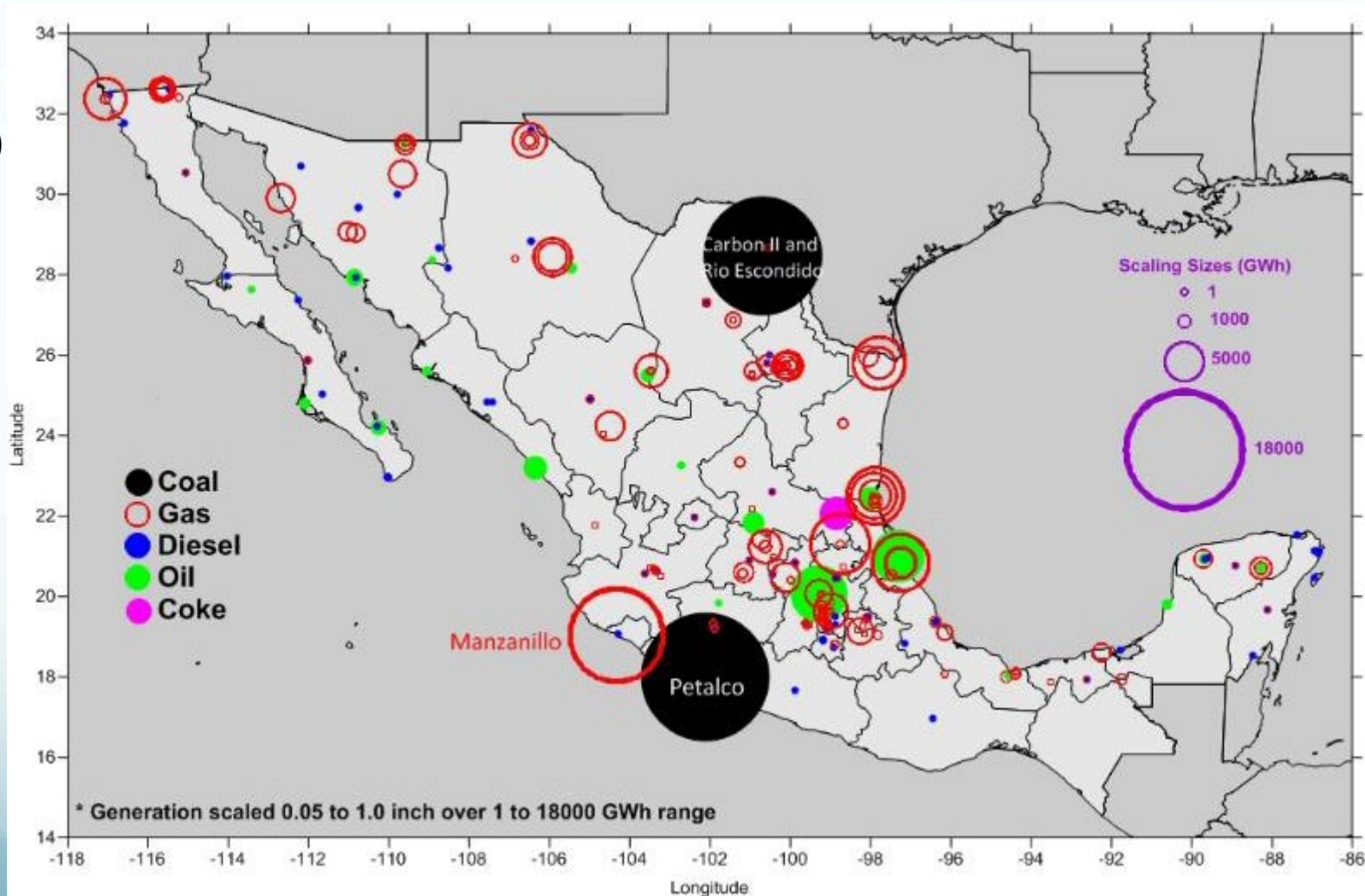
TG: 58

Oil (29)

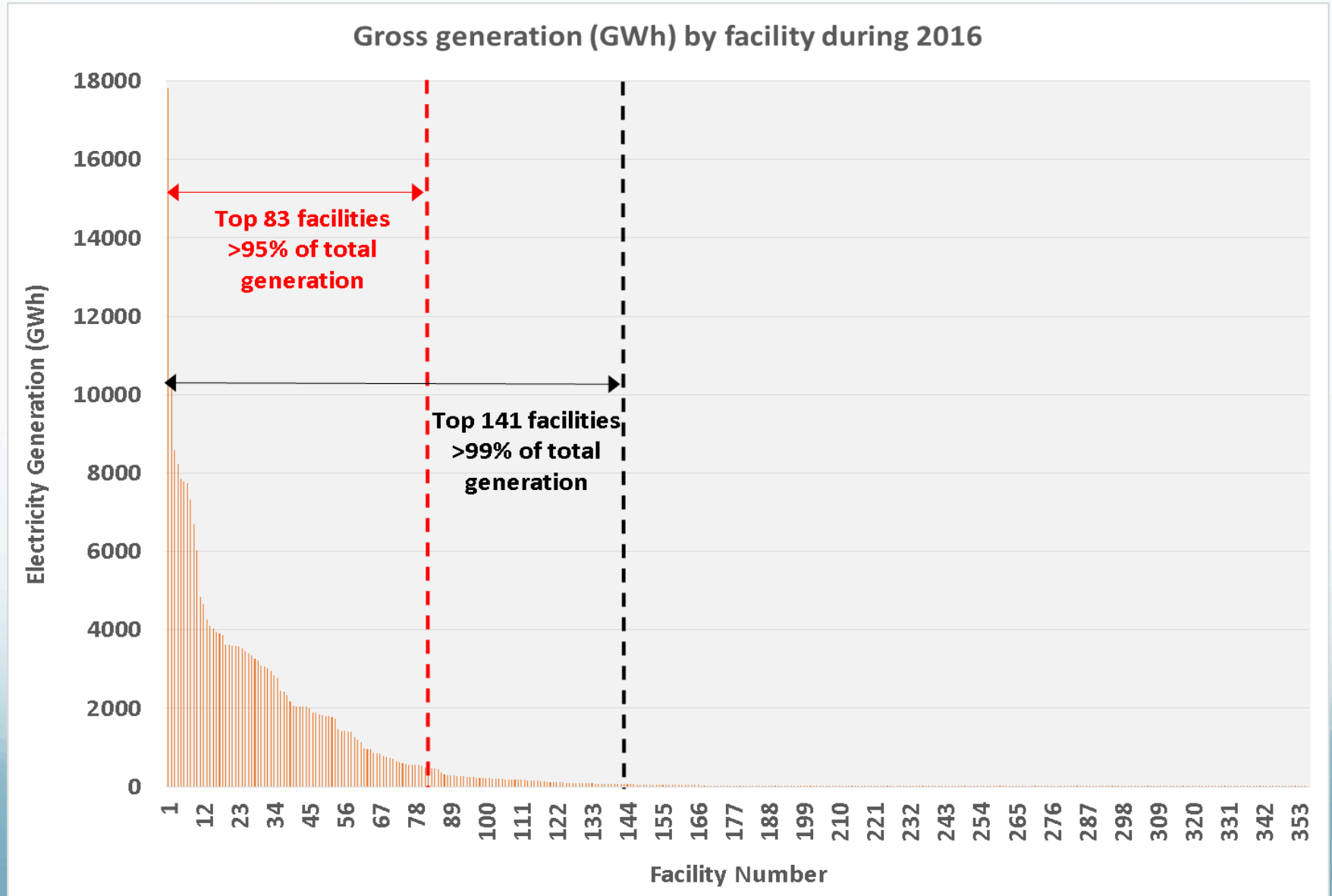
Conv: 23

IC: 6

OTH: 2



2016 Electricity Generation by EGU



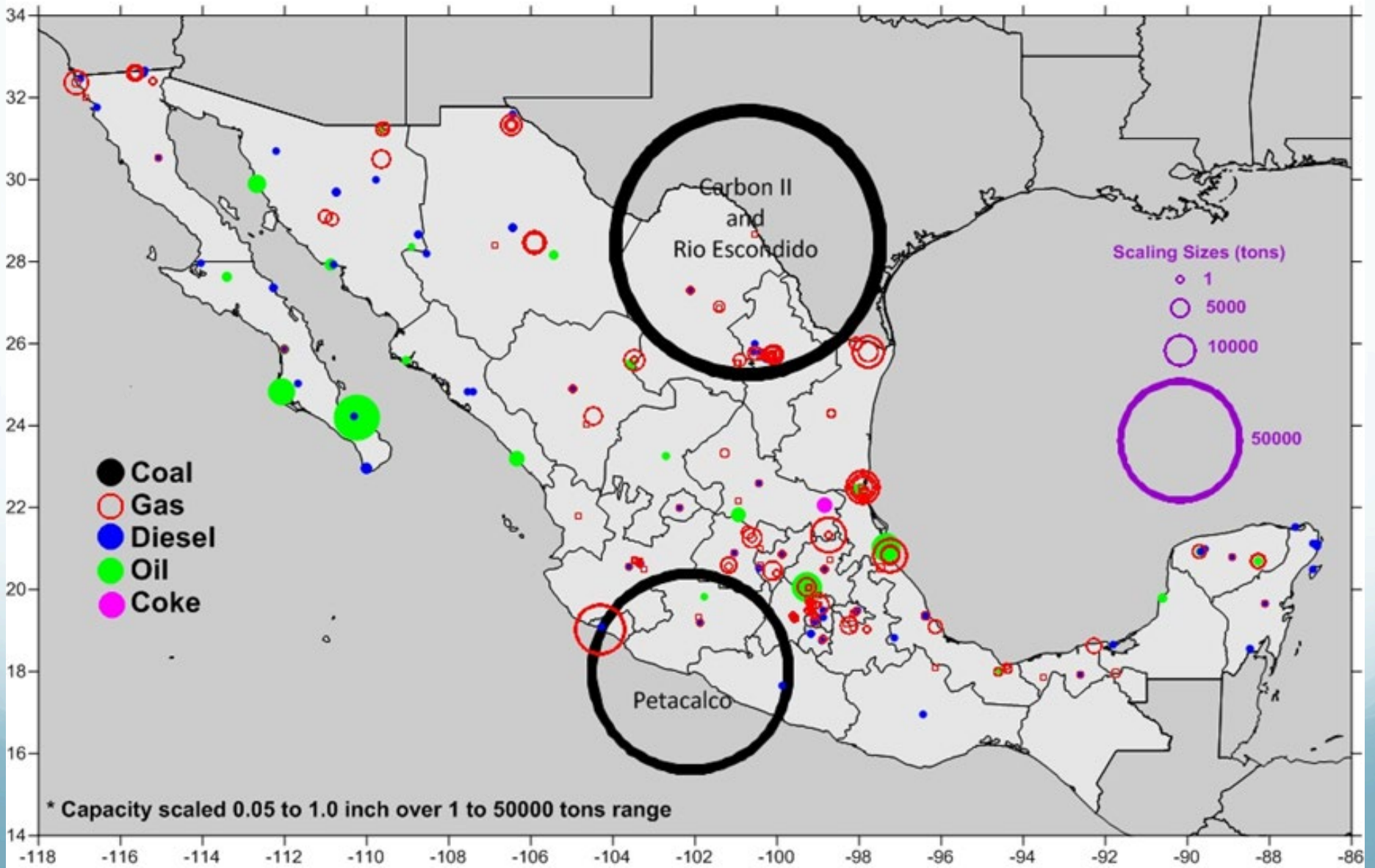
Electricity Generation Unit (EGU) Emissions Methodology

- Spatial scale of individual EGUs
- NO_x , CO, SO_2 , VOC, $\text{PM}_{2.5}$, PM_{10} , NH_3
- Leveraged the PRODESEN and related datasets for annual generation (GWh) and EGU descriptive parameters
- Applied COPAR (2015) emissions factors (kg/GWh)
- COPAR data available for ~50% of EGUs; otherwise employed factors averaged by fuel and technology

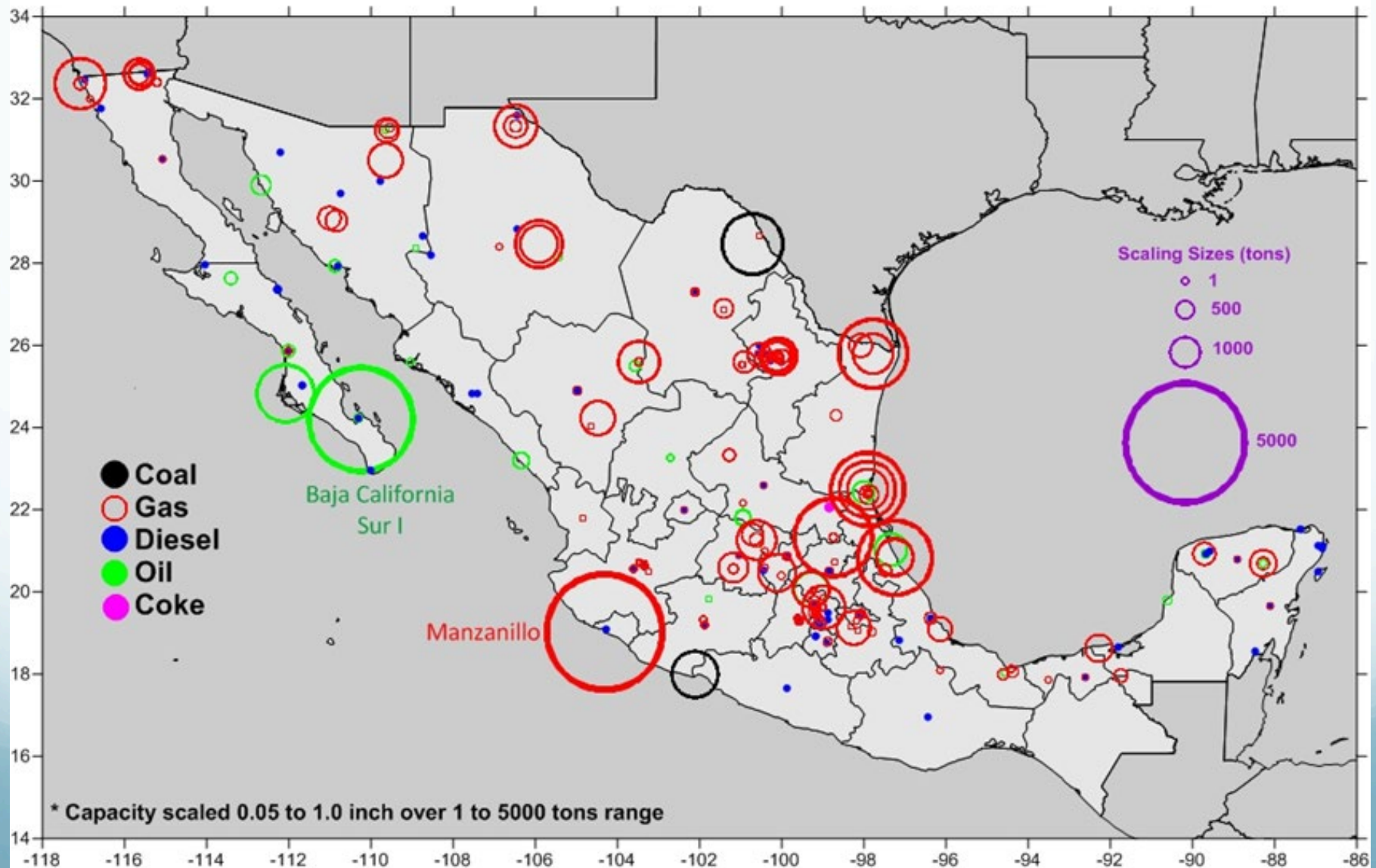
2016 Annual EGU Emissions Results (tons)

Fuel	NO _x	CO	SO ₂	VOC	PM _{2.5}	PM ₁₀	NH ₃
Coal	188435	3948	235116	318	922	3534	1
Coke	3205	102	10963	12	168	171	0
Natural Gas	263686	66402	29326	2014	6419	6419	3508
Diesel	6293	109	33906	35	80	80	47
Oil	65549	12397	549947	858	17827	27123	1980
Total	527,167	82,959	859,258	3237	25,417	37,328	5493

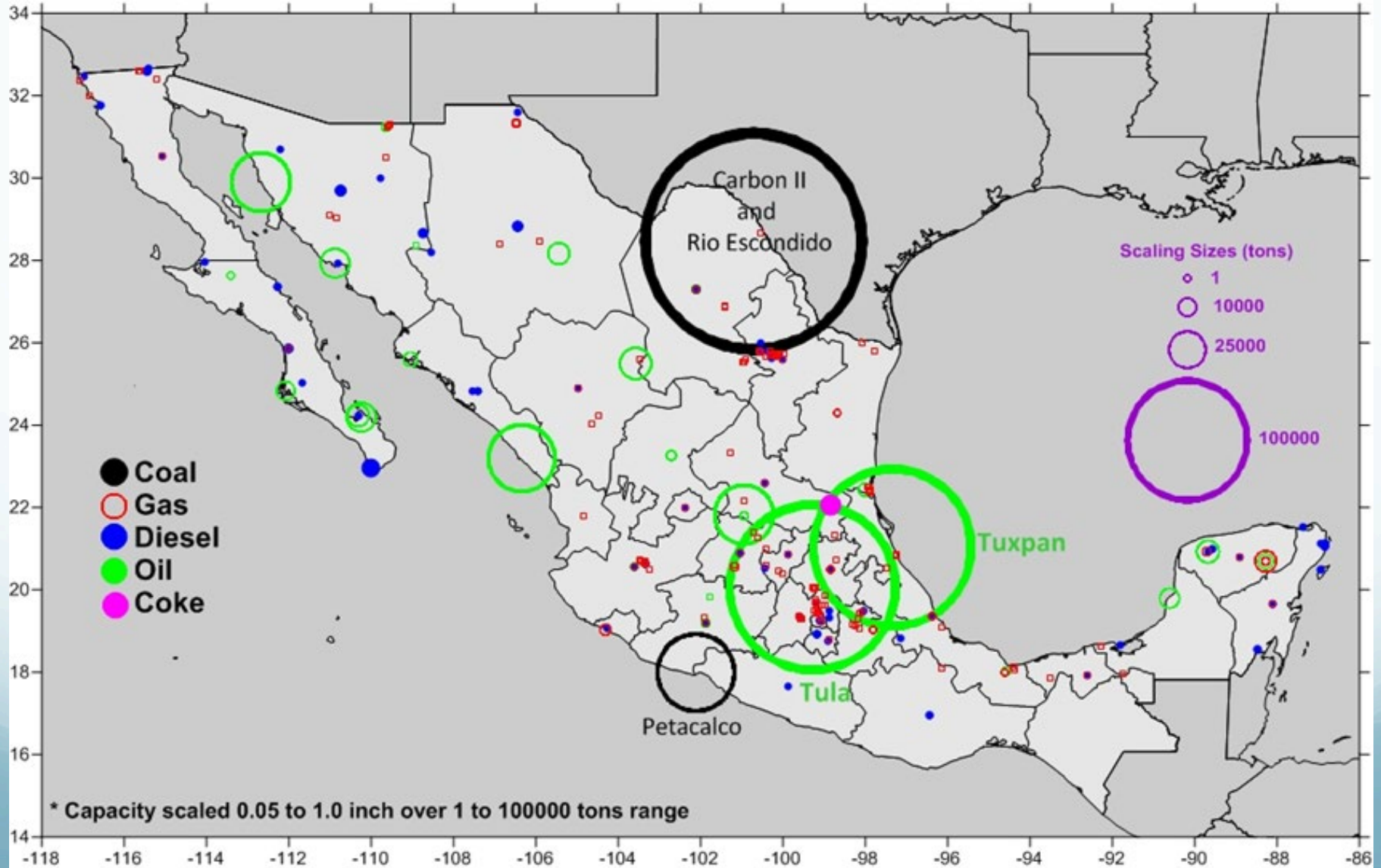
2016 EGU NOx (tons)



2016 EGU CO (tons)



2016 EGU SO₂ (tons)



Finalized 2016 EI deliverable datasets

- Annual EI for each upstream and midstream source group (7 individual data files in total) in AFS (AIRS Facility System) format
- Chemical speciation profile recommendations (generally based on TCEQ current cross reference SCC/profile results gap-filled with EPA defaults)

Round One

- 1.1 Shallow water (July 15, 2015)
- 1.2 Shallow water (September 30, 2015)
- 1.3 Onshore conventional (December 15, 2015)
- 1.4 Deepwater (December 5, 2016)

Round Two

- 2.1 Shallow water (June 19, 2017)
- 2.2 Onshore conventional (July 12, 2017)
- 2.3 Onshore conventional (July 12, 2017)
- 2.4 Deepwater (January 31, 2018)

Round Three

- 3.1 Shallow water (March 28, 2018)

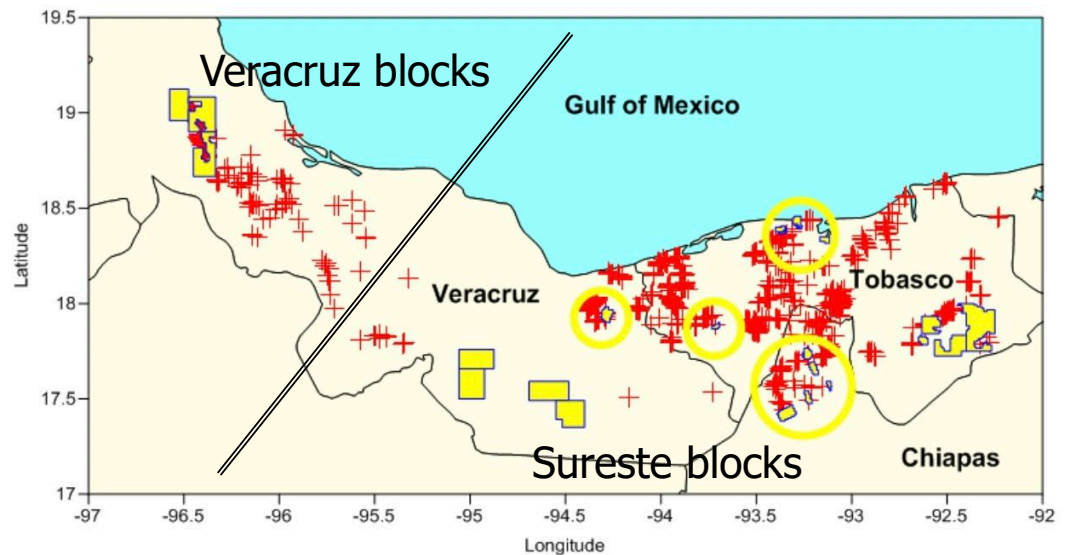
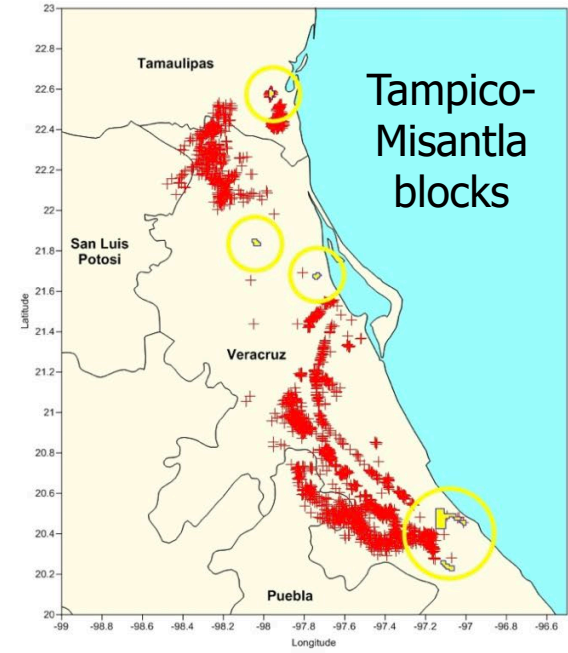
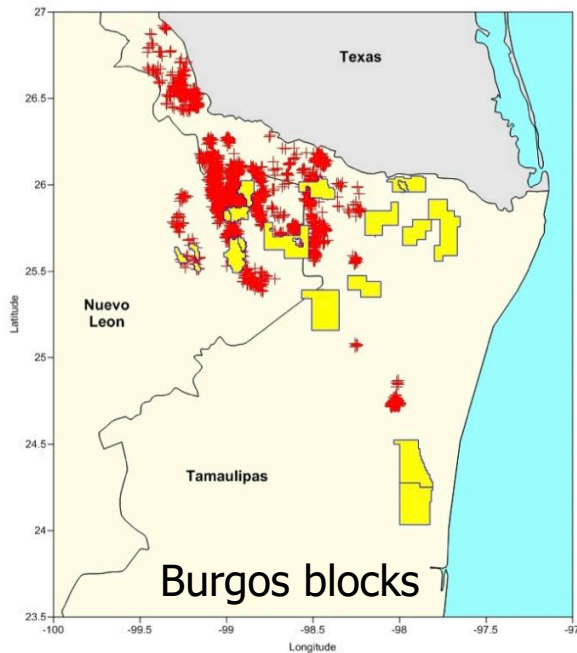
Stages within rounds characterized by **location** (shallow water, deepwater, onshore conventional or unconventional), **type of activity** (exploration and/or extraction), **contract type** (license or production sharing)

Effects of Presidential Transition on Bid Rounds

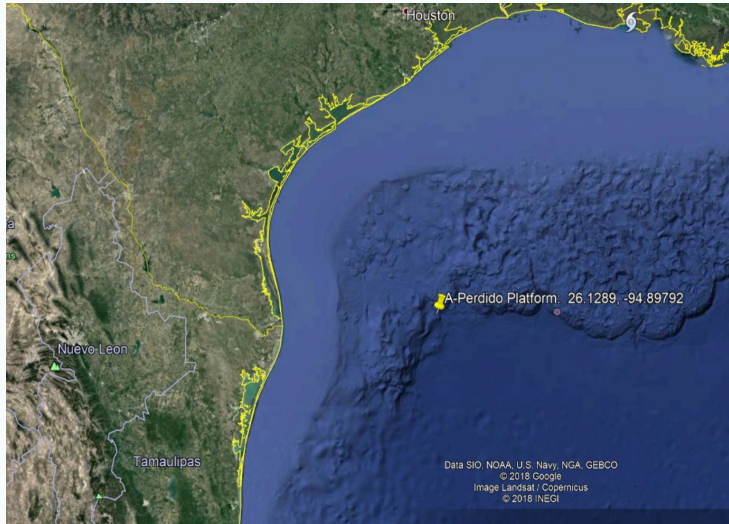
- Andrés Manuel López Obrador took office on December 1, 2018
- Announced suspension of new bid rounds
- Expressed opposition to hydraulic fracturing*
- Two additional stages in Round 3 suspended: 3.2 (onshore conventional blocks) and 3.3 (onshore conventional and unconventional blocks)
- Contracts awarded in the bid rounds are continuing
- Currently **111 current exploration and extraction contracts**: 104 from the bid rounds (with one early termination), 3 farmouts, 5 Pemex contract migrations

Onshore 2016 Active Well Locations and Awarded Blocks

Future emissions estimated by assuming **20% increase** in 2016 emissions by basin and distributing emissions across all blocks in proportion to their spatial areas within that basin



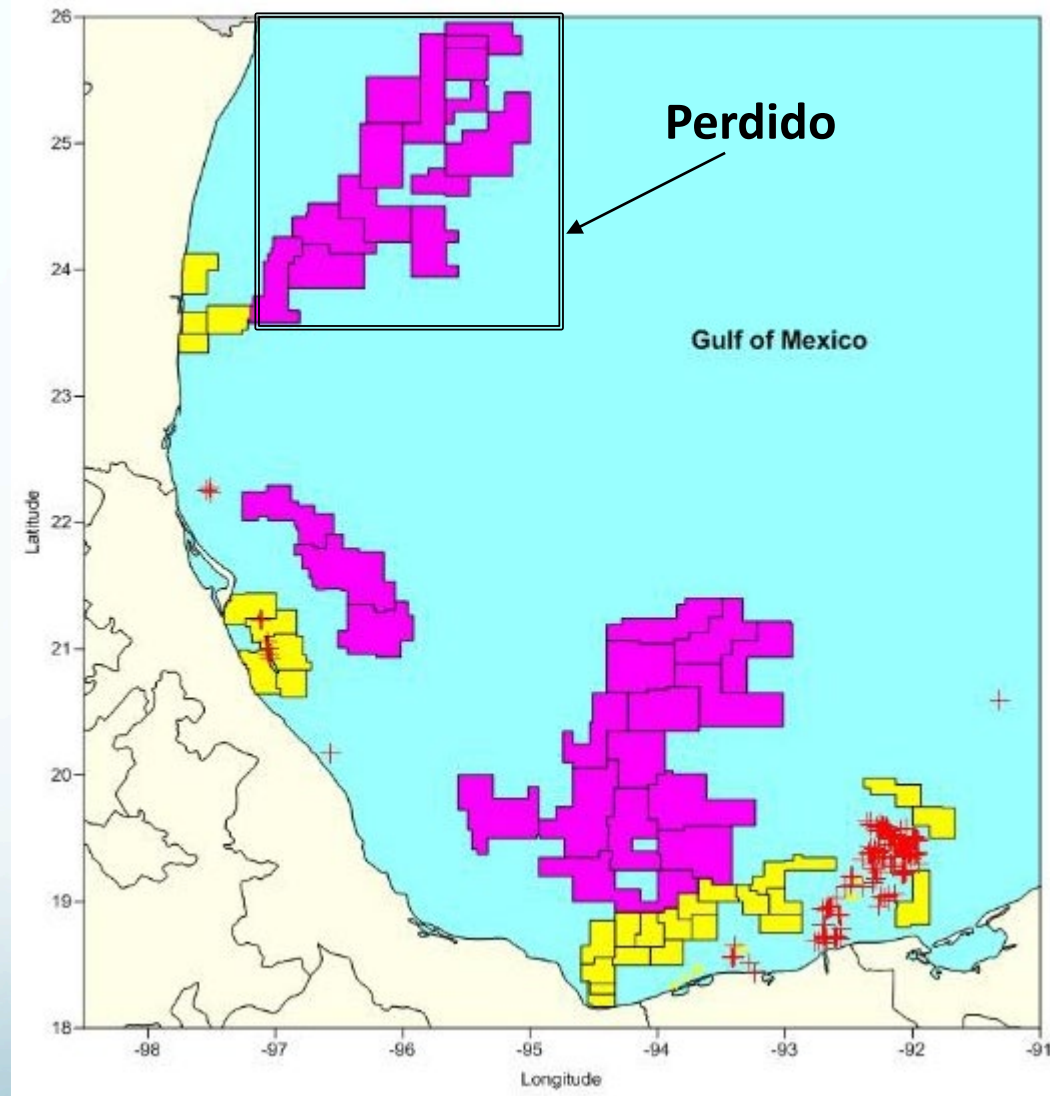
Shallow Water Active Well Location in 2016 and Awarded Shallow Water and Deepwater Contractual Areas



Future emissions:

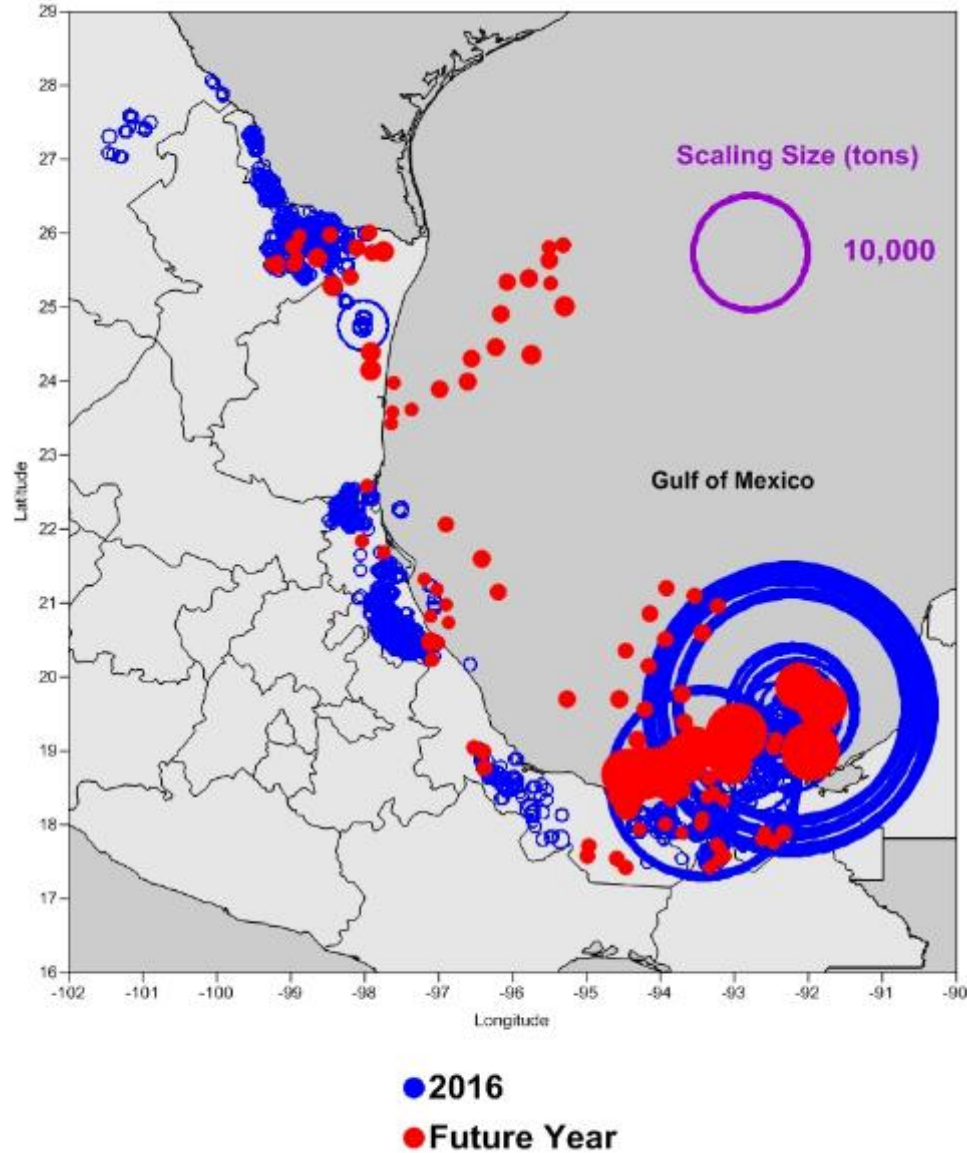
Shallow water: 20% increase by basin in 2016 emissions in Western Gulf or Bay of Campeche

Deepwater: Single platform in 50% of Perdido blocks with 2014 annual emissions for **A-Perdido**; Same totals for Perdido applied across remaining combined deepwater areas



Source: <https://rondasmexico.gob.mx/eng/rounds/>

2016 and Projected Future Year NO_x Emissions



Summary and Recommendations

- Developed bottom-up assessment of 2016 base year emissions for Mexico to support air quality modeling : onshore and offshore oil and gas exploration and production well sites, well flaring, natural gas compressor stations, natural gas processing plants, EGUs
- Illustrated areas where future development of Mexico's oil and gas resources is likely and conducted speculative assessment of emissions that could accompany ongoing development
- Recommendations:
 - On-going need for Mexico-specific data and improved understanding of implementation of emission controls and technological improvements
 - Monitor contract progress and adjust inventories accordingly

Acknowledgment

The preparation of this presentation was funded by a grant from the Texas Air Quality Research Program (AQRP) at The University of Texas at Austin through the Texas Emission Reduction Program (TERP) and the Texas Commission on Environmental Quality (TCEQ). The findings, opinions and conclusions are the work of the author(s) and do not necessarily represent findings, opinions, or conclusions of the AQRP or the TCEQ.