

# SF<sub>6</sub> Free Alternative Medium and High Voltage Circuit Breakers: Vacuum Technology

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+1 571-348-5774



# SF<sub>6</sub> Free Alternative Medium and High Voltage Circuit Breakers: Vacuum Technology

Volha Roshchanka  
Program Manager, USEPA  
September 14, 2020

[www.epa.gov/f-gas-partnership-programs/electric-power-systems-partnership](http://www.epa.gov/f-gas-partnership-programs/electric-power-systems-partnership)



# Webinar Housekeeping Items



- **This webinar is being recorded.**
  - A recording will be available on EPA's partnership website: <https://www.epa.gov/f-gas-partnership-programs/electric-power-systems-partnership>
- **All lines will be muted during the presentation. Please turn your video off to prevent lagging.**
- **There will be a Q&A at end of webinar.**
  - You may submit questions at any time during the presentation using the chat feature.
  - You can minimize and maximize the chat window at any time during the presentation.
- **Email partnership at: [SF6Partnership@epa.gov](mailto:SF6Partnership@epa.gov)**



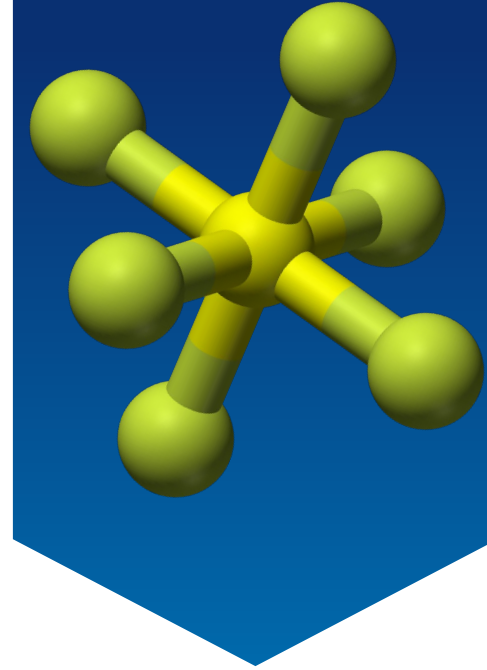
# Electric Power Systems Voluntary Partnership for SF<sub>6</sub>

**Mission:** To reduce emission of sulfur hexafluoride (SF<sub>6</sub>), a potent greenhouse gas, through voluntary, cost-effective technical and management solutions.



# Sulfur Hexafluoride

- SF<sub>6</sub> is a human-made gas emitted from:
  - electrical transmission and distribution equipment
  - manufacture of electronics / semiconductors
  - production of magnesium
- SF<sub>6</sub> lasts ~3,200 years in the atmosphere
- SF<sub>6</sub> has a high global warming potential (GWP) compared to CO<sub>2</sub> over 100-year time scale:
  - 1 pound of SF<sub>6</sub> = 11.4 tons of CO<sub>2</sub> GWP
  - SF<sub>6</sub> GWP = 22,800<sup>a</sup> times CO<sub>2</sub>



<sup>a</sup> IPCC (2007) Climate Change 2007: The Physical Science Basis Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.

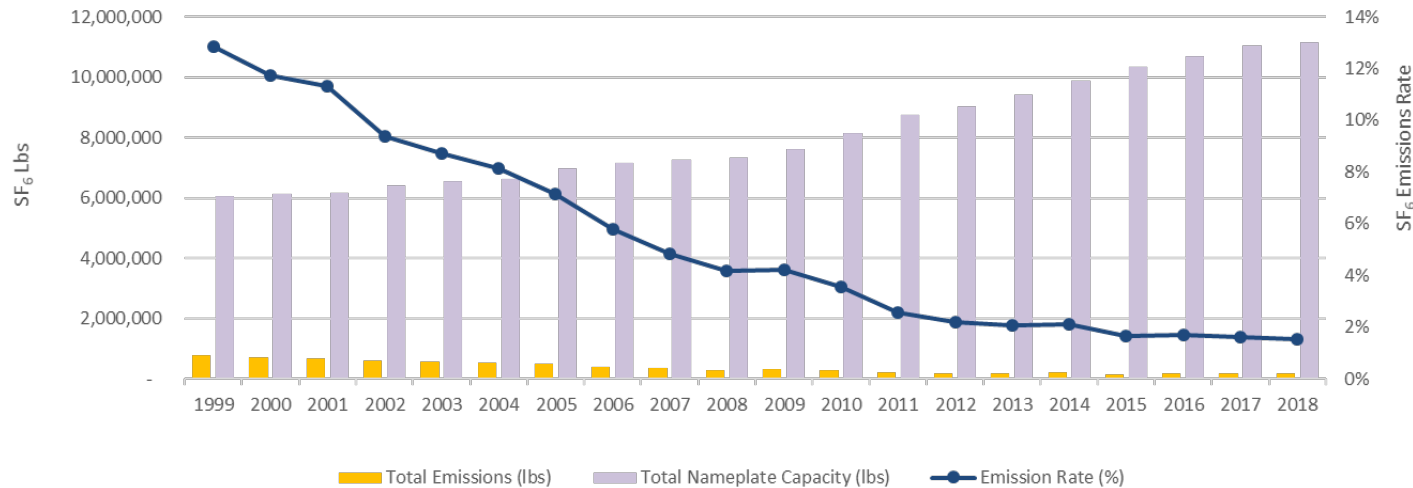
# About the Partnership

- Established in 1999 together with 45 Charter Partners
- Currently 90 Partner utilities representing approximately 50% of total U.S. grid transmission miles
- Total 2018 SF<sub>6</sub> nameplate capacity of partners: over 11 million lbs.
- Creates opportunities for collaboration between utilities to discuss best practices to reduce SF<sub>6</sub> emissions



# Partnership Accomplishments

SF<sub>6</sub> Partnership Accomplishments 1999-2018



- Between 1999 and 2018:
  - 78% decrease in SF<sub>6</sub> emissions of Partners
  - 88% decrease in emissions rate (emissions/nameplate capacity)
- Cumulative reductions of nearly 8 million lbs. of SF<sub>6</sub> (compared to 1999 levels)



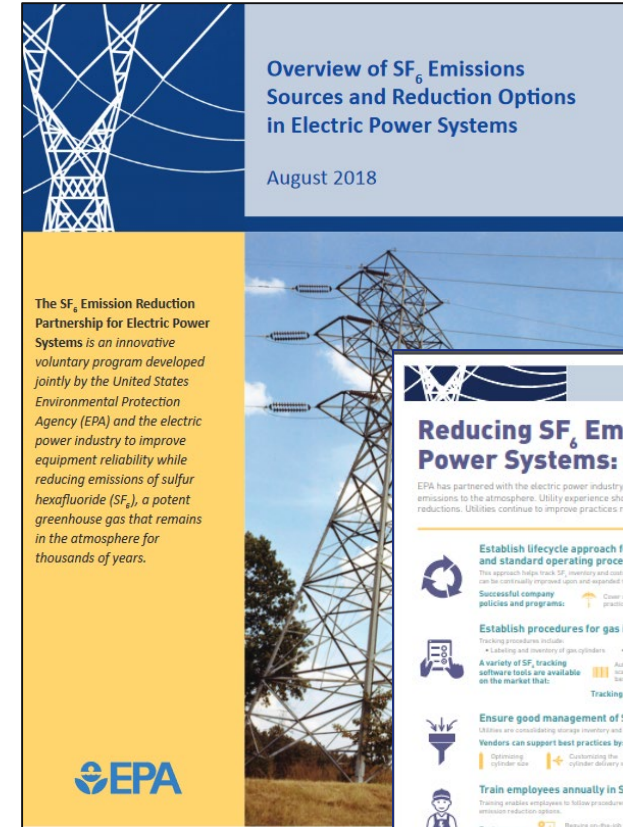


# Partnership Publications

## Report: Overview of SF<sub>6</sub> Emissions Sources and Reduction Options in Electric Power Systems

## Overview Poster: Reducing SF<sub>6</sub> Emissions in Electric Power Systems

All publication available online:  
<https://www.epa.gov/f-gas-partnership-programs/electric-power-systems-partnership>



# Partnership Publications

## Moving Toward SF<sub>6</sub>-Free High Voltage Circuit Breakers: Considerations for Adopting Vacuum Breaker and Fluorinated Gas Alternative Technologies

Thank you Partner utilities and technology manufacturers for providing information for this report!

The report cover has a blue header with a white electrical tower graphic on the left. The title is in white and yellow text. Below the title is a photograph of a modern building at night. The bottom section of the cover features a photograph of a worker on a transmission tower against a sunset sky. The EPA logo is in the bottom right corner.

430-R-20-006

### Moving Toward SF<sub>6</sub>-Free High Voltage Circuit Breakers:

*Considerations for Adopting Vacuum Breaker and Fluorinated Gas Alternative Technologies*

For additional resources, please visit:  
<https://www.epa.gov/t-gas-partnership-programs/electric-power-systems-partnership>.

#### Introduction

Over the last two decades, the SF<sub>6</sub> Emission Reduction Partnership for Electric Power Systems has offered utilities a platform to work together to reduce emissions of sulfur hexafluoride (SF<sub>6</sub>), a very potent greenhouse gas. These efforts included adoption and dissemination of best management practices and, more recently, exploration of alternatives to SF<sub>6</sub>. Although the industry has had success with non-SF<sub>6</sub> alternatives in low and medium voltage (up to 72.5 kV) equipment, alternatives for high voltage equipment have proven to be more challenging.<sup>1</sup> New high voltage non-SF<sub>6</sub> gas insulated alternatives have recently become more promising, with early adoption both in the United States and abroad. Utilities may consider new options as they strive to meet their own voluntary commitments, respond to state or local requirements<sup>2</sup> or manage their longer-term plans for decommissioning first generation SF<sub>6</sub> breakers or older oil-filled breakers. This document summarizes information about key alternatives for high voltage equipment, including recent developments and potential considerations for adopting -SF<sub>6</sub>-free insulated equipment. This work represents EPA's joint efforts with the industry to identify options for effective SF<sub>6</sub> emission reductions.

#### Objective

The focus of this overview is on two promising options to replace high voltage SF<sub>6</sub> equipment: 1) alternative vacuum circuit breaker technologies, and 2) alternative fluorinated gas mixtures. This document does not cover all alternatives or manufacturers offering alternatives to SF<sub>6</sub> high voltage equipment, nor does it serve as an exhaustive list of current and future industry developments due to the dynamic nature of this topic. Mention of specific companies or products does not constitute endorsement by EPA.

<sup>1</sup>In the United States, electric power systems are nationally classified according to the following voltage classes, per ANSI C84.3-2016:

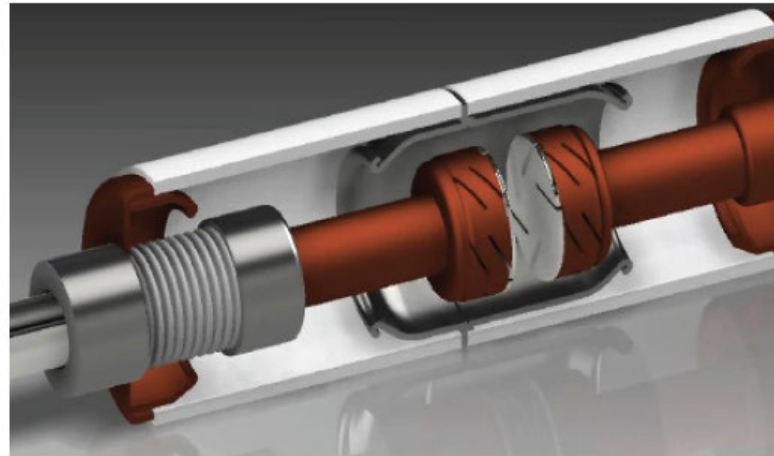
- Low Voltage: 1,000 volts or less
- Medium Voltage: greater than 1,000 volts and less than 100 kV
- High Voltage: greater than 100 kV and equal to or less than 230 kV
- Extra-High Voltage: greater than 230 kV but less than 1,000 kV
- Ultra-High Voltage: equal to or greater than 1,000 kV

(Some states have different approaches to classifying electric power systems.)

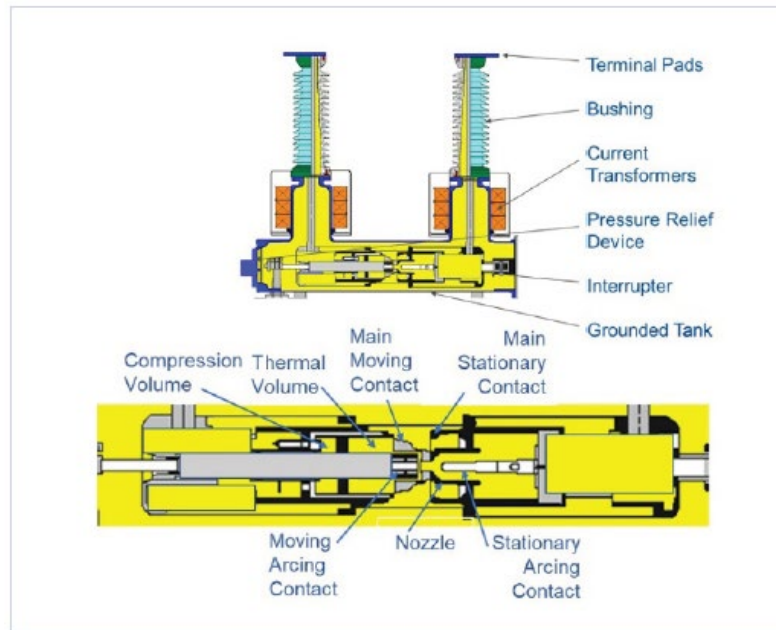
<sup>2</sup>For example, the California Air and Resources Board and Massachusetts Department of Environmental Protection have set mandatory emission rate maximums, reporting procedures, SF<sub>6</sub> gas recovery and recycling requirements, and, most recently, proposals in the state of California to phase out SF<sub>6</sub>. At the local level, cities such as Seattle have reporting requirements that may incentivize utilities to reduce SF<sub>6</sub> consumption.

The EPA logo is located in the bottom right corner of the report cover.

# Publication: Moving Toward SF<sub>6</sub>- Free High Voltage Circuit Breakers



Cutaway of an Interrupter Utilized in Vacuum Circuit Breaker Technology (Provided by Hitachi)



Schematic Diagram of Fluorinated Alternative Gas Circuit Breaker Technology (Provided by GE Grid Solutions)

## What is covered:

- Technologies in focus:
  1. Vacuum circuit breakers
  2. Fluorinated gas alternative technologies
- Properties of alternative mediums used in SF<sub>6</sub>-free technologies
- Considerations for technology adoption
  - Capital costs
  - Operational and maintenance (O&M) costs
  - Footprint
  - Standards for alternatives
  - On the grid piloting
- Example installations of medium & high voltage alternative equipment



# Looking Ahead (2020-2021)

- Continue to focus on updating technical information and sharing best practices
- Update Partnership website with additional resources
- Looking forward to new ideas and collaborations
- Please get in touch at [SF6Partnership@epa.gov](mailto:SF6Partnership@epa.gov)

[www.epa.gov/f-gas-partnership-programs/electric-power-systems-partnership](http://www.epa.gov/f-gas-partnership-programs/electric-power-systems-partnership)



# Today's Agenda



## SF<sub>6</sub> Free Alternative Medium & High-Voltage Circuit Breakers

- 1. Alternative Technologies for Substation Gas Insulated Equipment:  
It Can Be Done!**
  - Linus Farias and Brian Farmer (Pacific Gas & Electric)
- 2. Building the Future of Energy**
  - Julia Green and Neil Hutchins (Southern Company)
- 3. Circuit Breakers: Vacuum Technology**
  - Joseph Lookup and Kyle Supinski (PPL Electric Utilities)

**AGENDA:  
SF<sub>6</sub> Free  
Alternative  
Medium and  
High  
Voltage  
Circuit  
Breakers**



## Pacific Gas and Electric

### Alternative Technologies for Substation Gas Insulated Equipment: It Can Be Done!

Linus Farias



Brian Farmer





# Alternative Technologies for Substation Gas Insulated Equipment: *It Can Be Done!*

Linus Farias  
Brian Farmer

September 14, 2020





# About us

As of May 2019

We are focused on providing safe, reliable, clean and affordable natural gas and electricity to our customers.

Service Area

**70,000** SQUARE MILES



Service area population

**16 million** CALIFORNIANS



(That's 1 in 20 Americans!)

**24,000**

EMPLOYEES WHO LIVE AND WORK

in the communities we serve



NEARLY

**400,000+**

SOLAR ROOFTOPS CONNECTED TO OUR GRID

about 1 in 5 nationwide





# Our Motivation

## Mission & Vision

**MISSION:** To safely and reliably deliver affordable and clean energy to our customers and communities every single day, while building the energy network of tomorrow.

**VISION:** With a sustainable energy future as our North Star, we will meet the challenge of climate change while providing affordable energy for all customers.

## Actions

- Million Ton Challenge
  - 1MMT CO<sub>2</sub>e operational emissions reduction by 2022
- CARB 2021 Regulation: SF<sub>6</sub> Phase-out mandates
  - Support California 2045 Carbon Neutrality Goal



# Million Ton Challenge: 2020 SF<sub>6</sub> Actions



**Repair or replace 20 circuit breakers** with the highest SF<sub>6</sub> leak rates



**Reduce SF<sub>6</sub> cylinder inventory by 33%:**

- Maintenance: 150
- Construction: 250



**Test 72kV and 115kV SF<sub>6</sub>-free circuit breakers and 115kV Gas Insulated Switchgear**



**Amend PG&E's Qualified Supplier List** to remove all 72kV equipment that contains SF<sub>6</sub>



**Develop Charter and Roadmap** to eliminate SF<sub>6</sub> use in equipment



# History of California's SF<sub>6</sub> Regulations



2006  
AB32 Enacted

2008  
AB32 Scoping Plan  
– Early Action Measures

2009  
SF<sub>6</sub> Regulation:  
Eliminating niche uses of SF<sub>6</sub>  
– Mg casting, fume hood testing, tracer testing

2009  
SF<sub>6</sub> Regulation:  
Semiconductor Operation emissions limit

2010  
SF<sub>6</sub> Regulation:  
Reducing SF<sub>6</sub> emissions from Gas Insulated Switchgear

1% SF<sub>6</sub> leak rate maximum by 2020

2011  
Reduction/  
Elimination regulations implemented

2014: \$383k in penalties for emissions exceedance

2016  
SB32 Enacted

2017  
Proposed Amendment to phase out SF<sub>6</sub> in Gas Insulated Switchgear

2020+  
1% Maximum Annual SF<sub>6</sub> Emissions limit; SF<sub>6</sub> phase-out starting in 2025



## 2010 Regulation

- 1% maximum annual emissions rate starting in 2020
- Extensive Recordkeeping & Reporting
- Strict Enforcement provisions
  - 8 enforcement actions  
\$10k - \$254
  - Emissions exceedances
  - Administrative errors

## 2020 Proposed Regulation

- Phase-out of SF<sub>6</sub> GIE :  
2025 – 2032
- 1% maximum annual leak limit
  - Ratchet down to 0.95% in 2035+
- Early Action Credit for SF<sub>6</sub> alternative GIE  
(installed prior to Phase-out dates)
- Case-by-case CARB exemption for SF<sub>6</sub> GIE that cannot be phased out





# SF<sub>6</sub> Alternatives: Where are we Heading?

## SF<sub>6</sub> Phase-out Starting in 2025

Voltage (kV)	Short-circuit Current (kA)	Phase-out Date
38 < kV ≤ 145	< 63	January 1, 2025
	≥ 63	January 1, 2028
145 < kV ≤ 245	< 63	January 1, 2027
	≥ 63	January 1, 2031
> 245	ALL	January 1, 2033

CARB proposed Regulation; July 21, 2020

Similar Schedule for Distribution GIE



## Convincing Leaders & Stakeholders

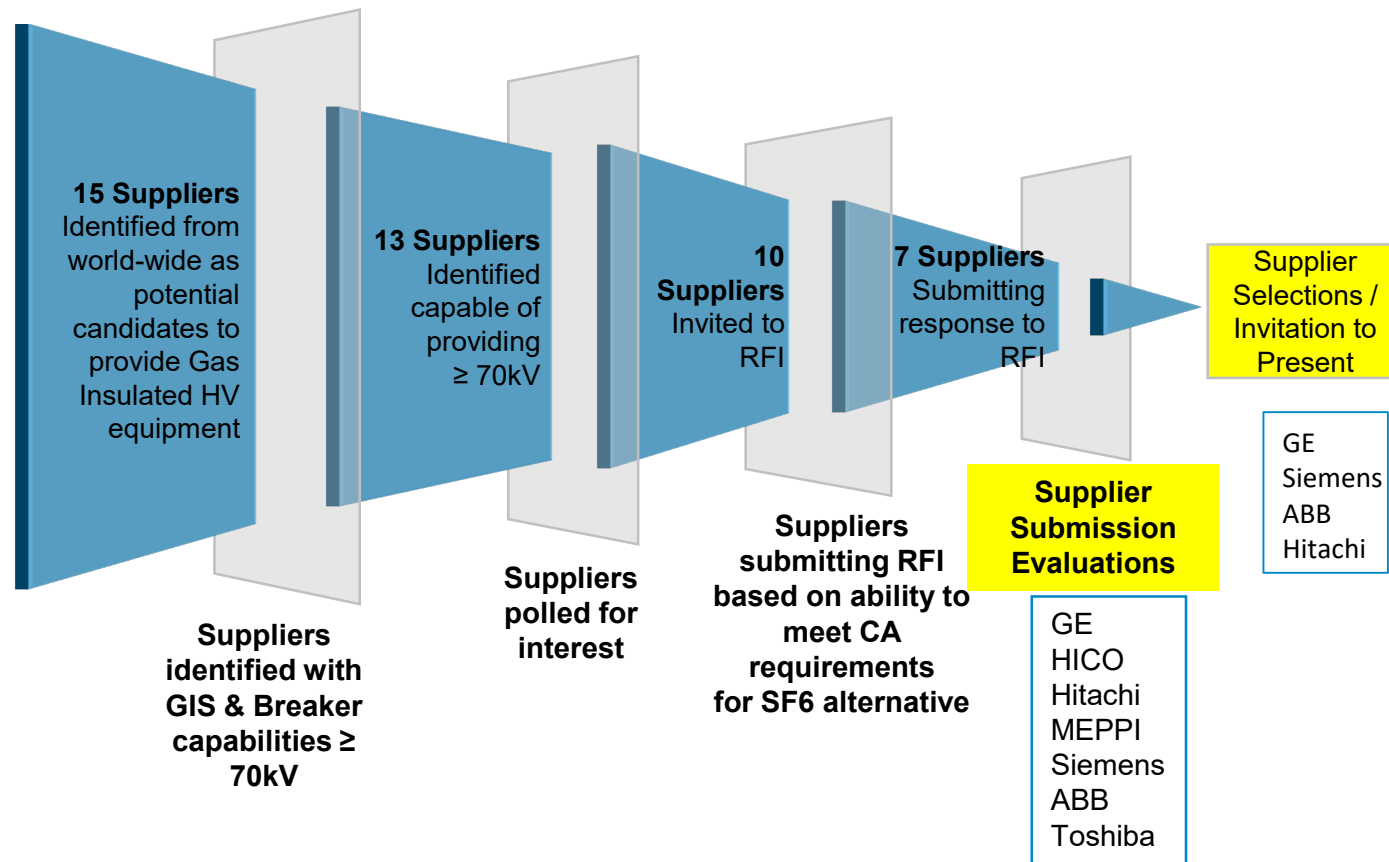
- **Recognize the Risks & Opportunity**
  - SF6: Highest known global warming potential (23,500)
  - SF6: Environmental persistence (3,200 years)
  - SF6: No available commercial waste gas management
  - **Dry-Air/Vacuum**: Safe and reliable alternative
- **Communicate the Value**
  - Initiate pilot projects and share findings with peer utilities
  - Encourage other utilities & stakeholders to pursue alternatives, create market need
  - Support Supplier communication with Regulators
- **Drive the Change**
  - Phase-out Charter and Roadmap
  - Collaborate with GIE Suppliers
  - Educate stakeholders: Leaders, Engineers, Project Managers
  - Support CARB Regulation
  - Support incentives: Fund pilot projects, Early Action Credit

- **Assess Substation Fleet\***
  - SF<sub>6</sub> (80%; 4,000 units)
  - Oil (20%/1,000 units)
  - VCB (0.1%; 15)
- **Define Pathway to Introduce Alternatives**
  - SF<sub>6</sub> Phase-out Charter and Roadmap
  - Define Roles & Responsibilities
- **Engage Strategic Sourcing**
  - Request for Information → Request for Proposal → Vendor Selection
- **Fund Pilot Projects *without* identified Capital projects**

\* Substation Fleet data are approximated



## Dead Tank Circuit Breakers and Gas Insulated Switchgear





# SF<sub>6</sub> Alternatives: Work with OEMs, Regulators & Utilities

- **Frequent Communication & Exchange**
  - Education & Advocacy
  - Facilitate meetings with regulators
  - Encourage other utilities to pilot alternatives
- **Drivers and Challenges to Creating Change**
  - Utilities (Demand)
    - Company policy
    - Identify capital projects to cover costs
    - Competing Priorities: Introducing significant change during Wildfire and Bankruptcy crises
  - OEMs/Suppliers (Product)
    - Corporate inertia
    - Market demand: Securing multiple orders
    - Competitive advantage concerns
    - High level of customer engagement: Adapting to new concept of Partnering with the Utility
    - Change Driver example: PG&E & Siemens share corporate Carbon goals
  - Regulators (CARB)
    - Establish a working relationship: CA Joint Utilities Group advocated changes:
    - Staff turnover
    - Agency priorities with other regulations



# SF<sub>6</sub> Alternatives: Phase-out Roadmap

## Dead Tank Circuit Breakers

Substation	DTCB Order Date	DTCB Delivery Date	Comment
VARIOUS 50 Dry-Air ordered (Hitachi); 72.5 kV, up to 40kA; 15 installed to date		2017-2020	72.5 kV SF6 Breakers removed from supplier list  No technological problems with installations over past 3 years
Henrietta	December 1, 2019	Dec 1, 2020	Dry-air (MEPPI) 72.5 kV, 31.5kA, 3 units
Livermore	March 1, 2020	Jan 1, 2021	Dry-air (MEPPI) 72.5 kV, 31.5kA, 1 unit
Palo Alto	July 1, 2018	June 1, 2021	Dry-air (Siemens); 145 kV, 40kA, 6 units
Santa Rosa	February 1, 2020	June 1, 2021*	Dry-air (Hitachi) 145 kV, 40kA, 3 units
To Be Identified	November 1, 2020	December 31, 2022	145kV; 63kA, 3 units RFP: September 2020

\* Potential delay due to COVID19 & commerce disruptions





# SF<sub>6</sub> Alternatives: Phase-out Roadmap

## Gas Insulated Switchgear

Substation and Project ID	GIS Order Date	GIS Delivery Date	Comment
Livermore	2019	October 2022	Dry-Air (Siemens) 8VN1 115 kV, 50 kA
Hunters Point	March 1, 2020	2022	Dry-Air (Siemens) 115kV, 50kA GIS BAAH
Silicon Valley Switching Station	2022	2023	Dry-Air (TBD) 115 kV, 50 kA
Larkin	2024	2025	Dry-Air (TBD) 115 kV, 50 kA



# SF<sub>6</sub> Alternatives: Adopting a New Technology

## Economic, Planning/Logistics, Technical & Operational

- **Economic**

- Capital vs Lifecycle Costs: 15-20% higher capital cost; anticipate 20% lifecycle cost benefit
- Competing with off-the shelf (mature) products
- Competing Enterprise Priorities; Wildfire mitigation, Safety, System resilience

- **Planning & Logistics**

- Obtain firm commitments to utilize new technology
- Removed 72.5 kV SF6 GIE from the QSL in 2019
- Option to defer projects to accommodate new technology
- Unanticipated OEM manufacturing schedule changes: COVID19, Tariffs



# SF<sub>6</sub> Alternatives: Adopting a New Technology

## Economic, Planning/Logistics, Technical & Operational

- **Technical**

- Developing technical skills for maintenance technicians and system engineers
- Technical limitations of Vacuum breakers (shunt capacitors & shunt reactors)
- Design Standards: Dry-air vacuum are larger (10%) & heavier (15%)

- **Operational Adaptation**

- OEM Training with pilot project installation
- Field Bulletin on commissioning non-SF<sub>6</sub> GIE



# Key to Adopting a New Technology

## Motivation & Drivers for Change

- Corporate Commitment
- Public Expectations
  - *Clean, Sustainable & Carbon Neutral*
- Regulation

## Driving Change

- Planning: Charter & Roadmap
- Communication: Engage stakeholders early and often
  - Internal, Utility, Regulators, Suppliers
- Change Management:
  - Select projects with long lead times
  - Consider life-cycle project cost
  - Training for Operators
  - Monitor Progress

# Thank You

Linus Farias

[Linus.farias@pge.com](mailto:Linus.farias@pge.com)

Brian Farmer

[Brian.farmer@pge.com](mailto:Brian.farmer@pge.com)





**AGENDA:  
SF<sub>6</sub> Free  
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# Southern Company

## Building the Future of Energy

Julia Green



Neil Hutchins





# Southern Company

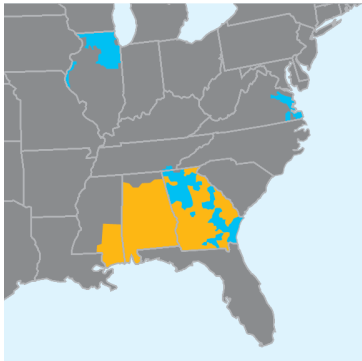
## Building the Future of Energy

Julia Green  
Neil Hutchins

September 14, 2020



# We Provide Clean, Safe, Reliable, Affordable Energy, Customized Solutions



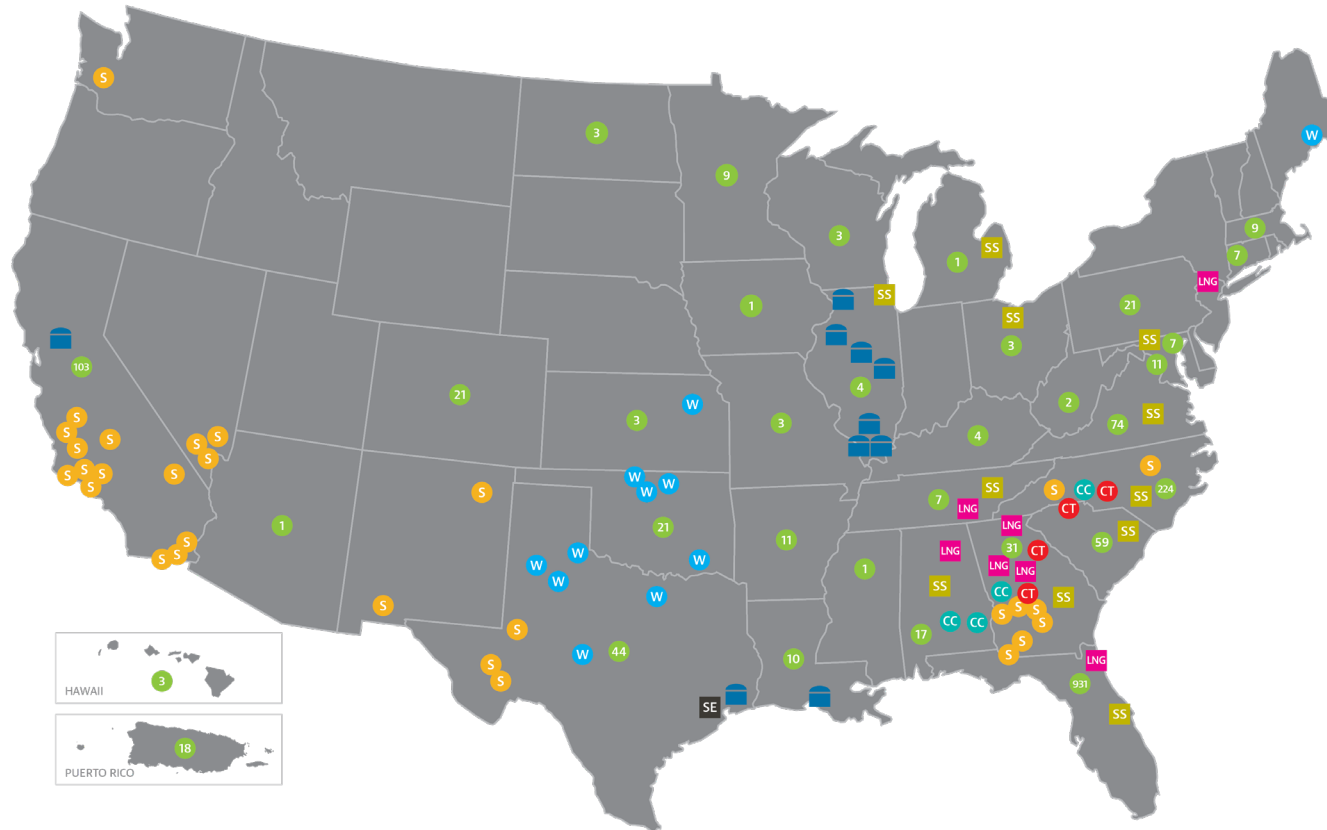
Service territories

- Electric
- Gas



Gas pipelines

- Southern Natural Gas
- Southern Company Gas
- Pipeline projects



- |  |  |  |
|--|--|--|
| <b>Southern Power</b>  | <b>Southern Company Gas</b>                                    | <b>PowerSecure</b>   |
| <span style="color: green;">■</span> Combined-cycle facility | <span style="color: pink;">■</span> LNG facilities             | <span style="color: green;">#</span> Owned and managed sites per state |
| <span style="color: red;">■</span> Peaking facility          | <span style="color: black;">■</span> Sequent Energy Management |  |
| <span style="color: green;">■</span> Biomass facility        | <span style="color: yellow;">■</span> SouthStar                |  |
| <span style="color: orange;">■</span> Solar facility         | <span style="color: blue;">■</span> Natural gas storage        |  |
| <span style="color: blue;">■</span> Wind facility            |  |  |

Capabilities in  
**50 States**

**7**  
Electric & Natural  
Gas Utilities

**9 Million**  
Customers

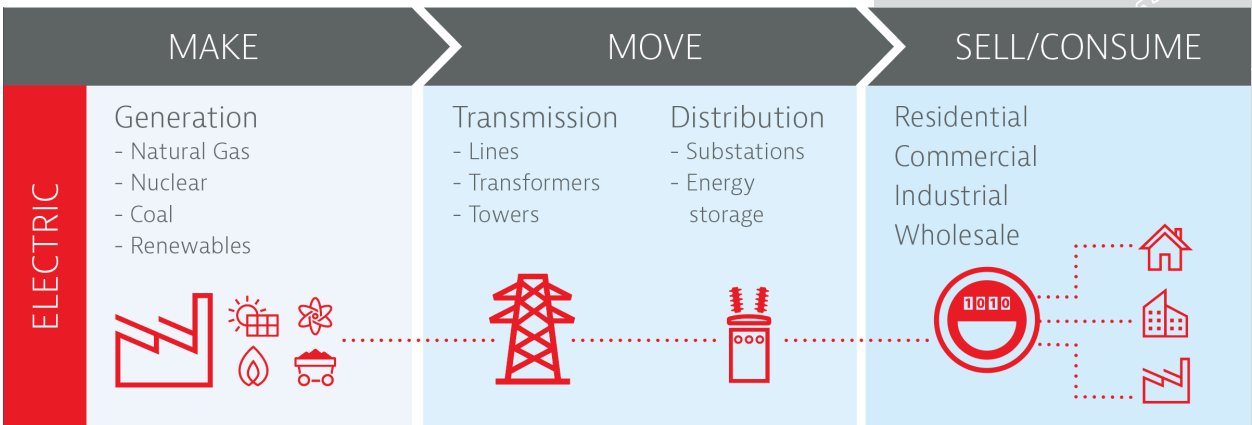
Approximately  
**29,000**  
Employees

Approximately  
**44,000 MW**  
of Generating Capacity

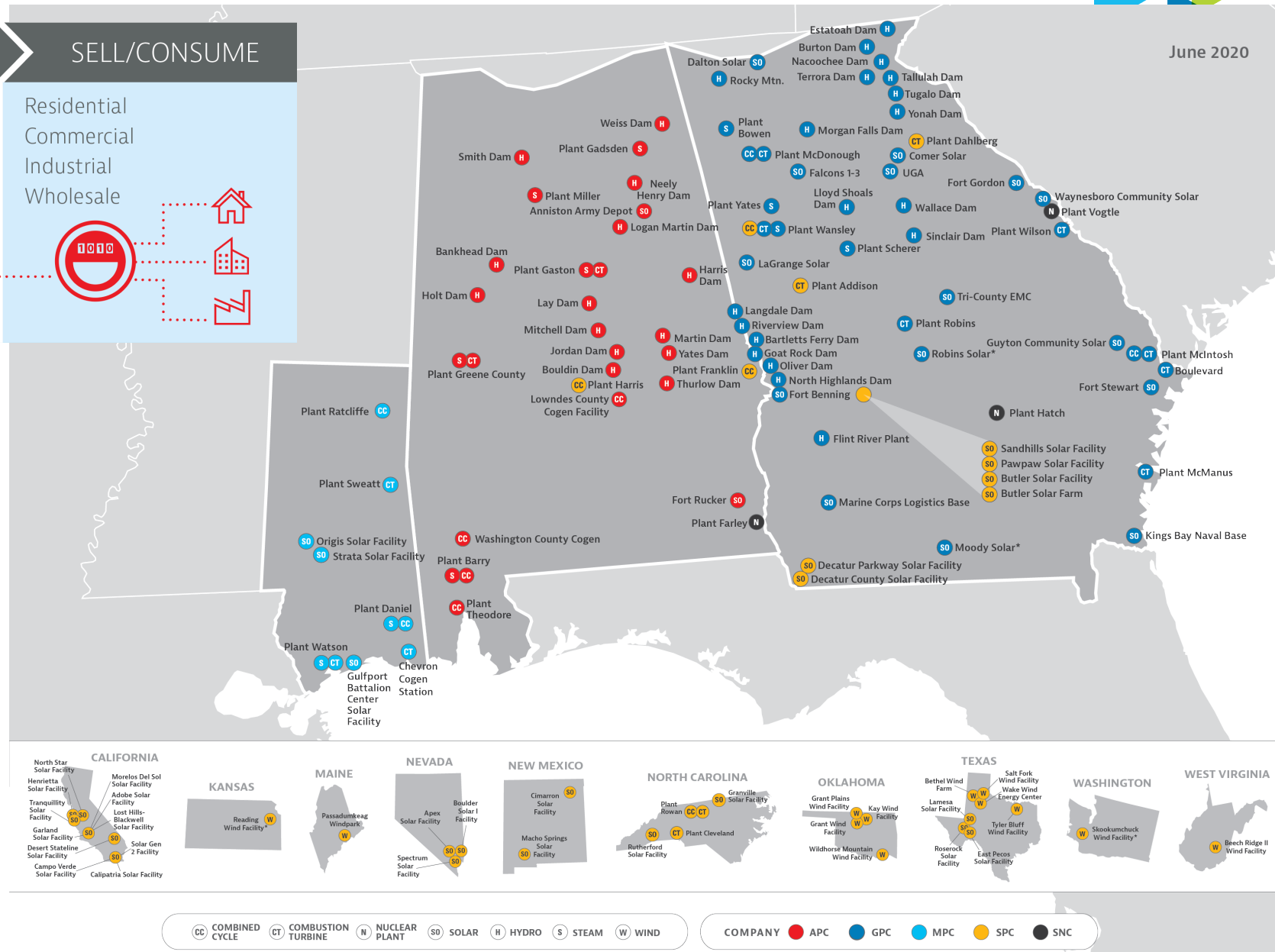
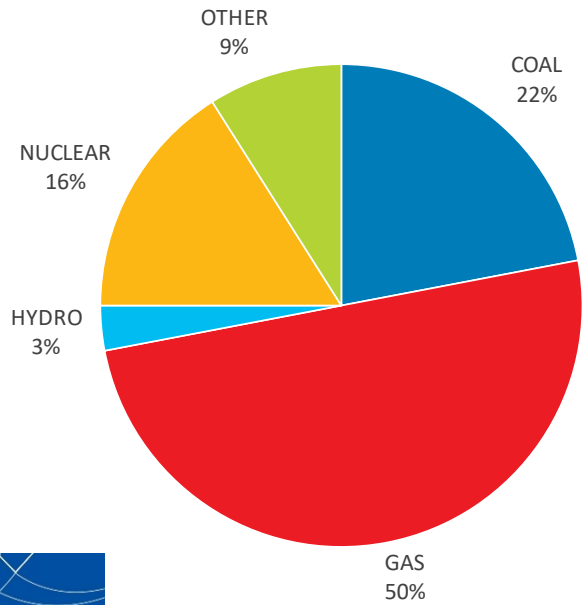
# Electric Generating Facilities



June 2020



## 2019 Total Generation Mix



\*Under development

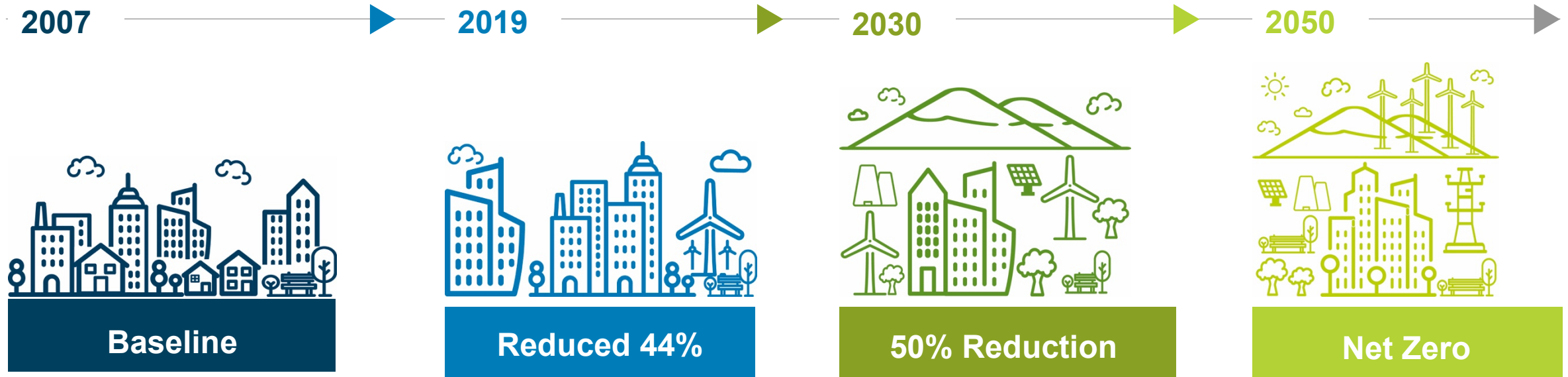


# Journey To A Net Zero Carbon Future



Southern Company has established an intermediate goal of a 50% reduction in carbon emissions from 2007 levels by 2030, along with, a long-term goal of net zero operations by 2050.

## GHG Emissions





# Impact of SF<sub>6</sub> Management



## The How's

Reducing SF<sub>6</sub> Footprint

Improving SF<sub>6</sub> Controls and Process

Non SF<sub>6</sub> Technology

Improving SF<sub>6</sub> Amounts on Nameplates of SF<sub>6</sub> Equipment

Sharing Best Practices Across the Company and Industry

# Impact of SF<sub>6</sub> Management



## Reducing SF<sub>6</sub> Footprint

- Replace older and problematic SF<sub>6</sub> Equipment
- Integrate Vacuum Technology at 72.5 kV and Below
- Investigate Polymer/Composite Bushings for SF<sub>6</sub> Equipment

# Impact of SF<sub>6</sub> Management



## Non-SF6 Gas

### Vacuum

- 38 kV & Less

### Clean Air Vacuum

- 72.5 kV Currently
- 115 kV Available 2021/2022
- 245 kV 2023/2024

### Novec gas

- Limited Availability
- Requires Specialized Equipment & Training

# Impact of SF<sub>6</sub> Management



- Improve Nameplate Capacity of SF<sub>6</sub> Accuracy
- Improve Seal & Gasket Designs
- Set Expectations of Leak Free/Low Leak Rates from Approved Manufacturers
- Have a Plan for Integrating Non-SF<sub>6</sub> Equipment

# Impact of SF<sub>6</sub> Management



Sharing Best Practices Across the Company & Industry

Increase Evaluation & Adoption of Newer Non-SF<sub>6</sub> Technology

Be Aware of HP Issues

- Non-SF<sub>6</sub> Technology Equipment Looks Similar to SF<sub>6</sub> Equipment
- Training on New Technologies & Processing Requirements
- Mixing SF<sub>6</sub> & Non-SF<sub>6</sub> Equipment in Same Facility
- Fully Understand the Performance of Non-SF<sub>6</sub> Equipment
- Safety
- Failure Modes of Non-SF<sub>6</sub> Equipment
- Testing & Investigation of Non-SF<sub>6</sub> Equipment



**AGENDA:  
SF<sub>6</sub> Free  
Alternative  
Medium and  
High  
Voltage  
Circuit  
Breakers**



**PPL**

**SF<sub>6</sub> Sustainability & Alternatives  
PPL Electric Utilities Transmission & Substation**

Joseph Lookup



Kyle Supinski





EDISON ELECTRIC CO.

# SF<sub>6</sub> Alternatives & Sustainability

## PPL Electric Utilities

### Transmission & Substation



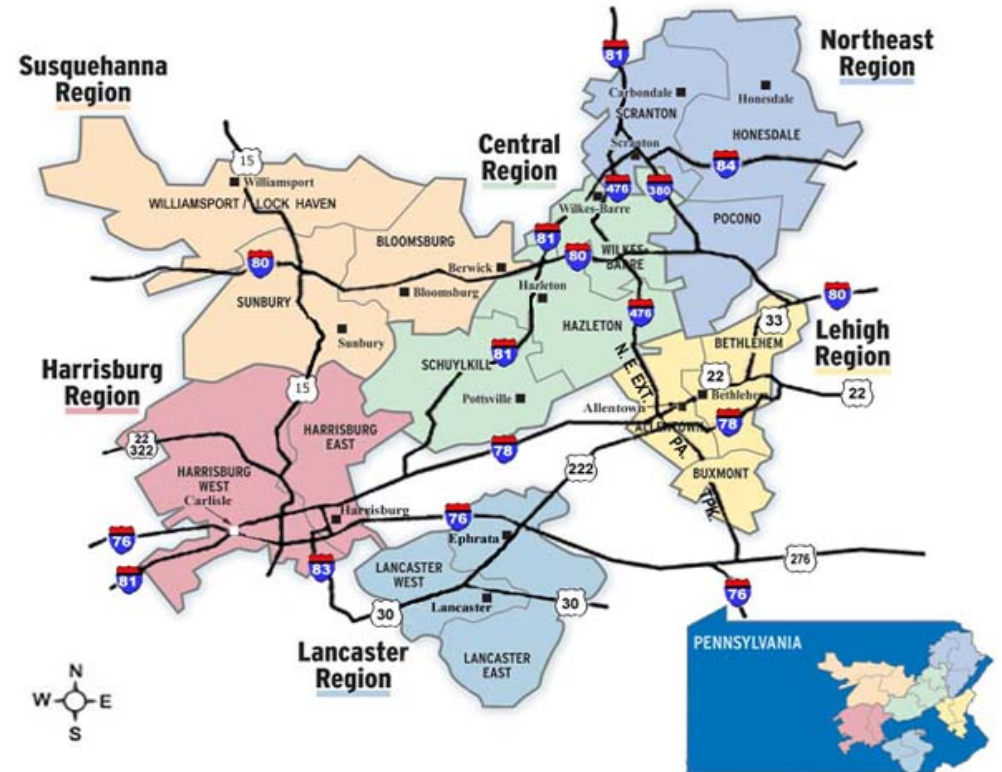
# PPL Electric Utilities by the numbers

- **1.4 million** customers in **29** Pennsylvania counties
- **Over 50,000** miles of power lines
- **10,000-square-mile** service territory

We **deliver electricity** to all homes and businesses in our service area.

- We don't produce power at power plants.
- We maintain and operate the delivery network – poles, wires, transformers, etc.

## PPL ELECTRIC UTILITIES SERVICE TERRITORY



# Our Parent Company

- **We're a subsidiary of PPL Corporation**
- FORTUNE 500® utility company
- Headquarters: **Allentown, Pa.**
- Global employees: **over 12,000**
- Annual revenue: **\$7.8 billion**
- **More than 10 million utility customer in US and U.K.**
  
- PPL Corporation operates award-winning utility companies in Kentucky, Pennsylvania and the U.K.
  
- PPL Corporation no longer owns Pennsylvania power plants after spinning off those operations into a new company. We own regulated Generation in Kentucky.







# Motivations Away from SF<sub>6</sub>

## Environmental Concerns:

- SF<sub>6</sub> gas has 23,900 times the impact of CO<sub>2</sub> in the atmosphere

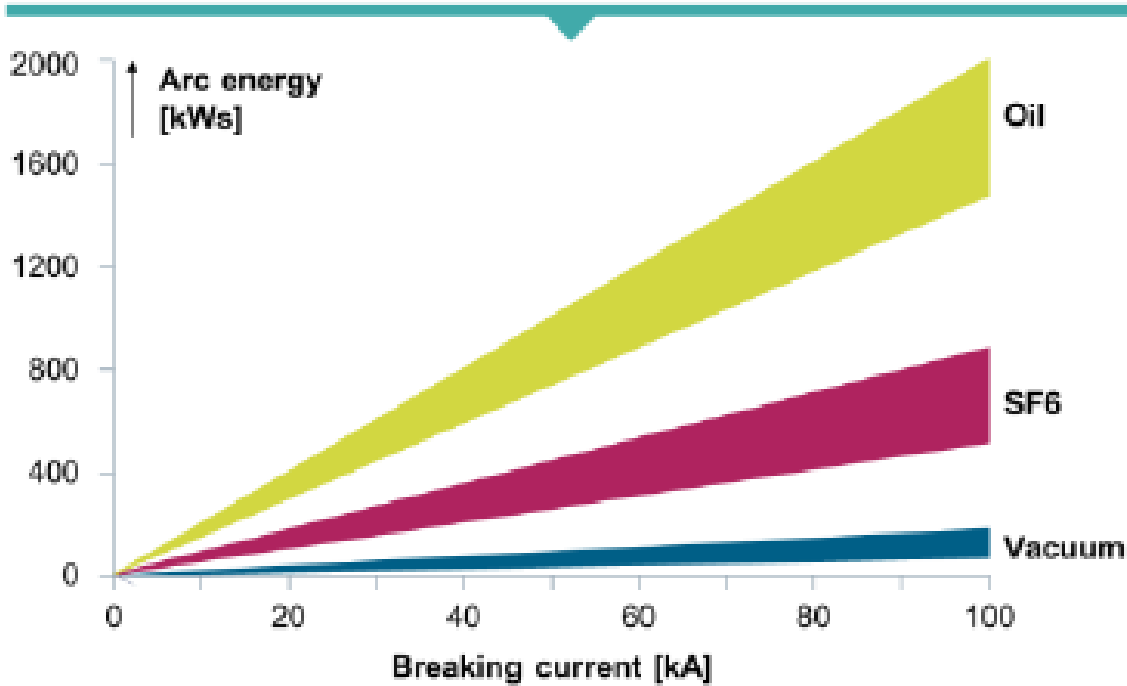
## Environmental Benefits of Vacuum (Dry Air):

- GWP (Global Warming Potential) = 0
- ODP (Ozone Depletion Potential) = 0
- Non-Toxic
- Non-Flammable
- No Gas exchange needed
- Eliminate reporting/recycling

GAS CHEMICAL COMPOSITION			
GAS NAME		Sulfur-hexafluoride	Dry-Air
Pure Gases	Chemical formula	SF <sub>6</sub>	N <sub>2</sub> (80%)/O <sub>2</sub> (20%)
	CO <sub>2</sub> - equivalent (GWP)	23,900	0
	Boiling Point (Celsius)	-64	< -183
	Dielectric Strength	1*	0.43
Gas Mixture	Carrier gas	None, N <sub>2</sub> or CF <sub>4</sub>	N <sub>2</sub> (80%)/O <sub>2</sub> (20%)
	CO <sub>2</sub> - equivalent (GWP)	23,900	0
	Boiling Point (Celsius)	- 64 (variable)	< -183
	Dielectric Strength	1*	0.43
Impact Arc	Decomposition products	Hydrofluoric acid, sulfur dioxide, sulfur compounds	Only if failure: ozone and nitrogen oxides

# Reliability

Endurance - Arc energy



- Excellent interrupting performance
- Increased durability – for maximum operations
- High reliability industry wide
  - Elimination of decomposition products
- Low temperature limits
- No maintenance

	Unit	GAS (SF <sub>6</sub> )	VACUUM
Rated Maximum Voltage	kV	72.5	72.5
Symmetrical Short Circuit Capability	KA	40	40
Continuous Current Rating	A	Up to 3000	Up to 3000
BIL	kV	350	350
Rated Interrupting Time	Cycles	5	3
Permissible number of operations at full fault current	Operations	10	40
Permissible number of open close operations at continuous current	Operations	6000	10000

# Proven Technology

- Existing Fleet of Oil, Gas, Vacuum
- Previous Experience at Medium Voltage (Distribution Class)
- One OEM has had technology available at 72.5kV DTCCB since 2007

## PPL EU Circuit Breaker Allocation by Type

Voltage Class	Oil	Gas (SF <sub>6</sub> )	Vacuum
12kV	13.5%	1.24%	85.27%



# Motivation Away from SF<sub>6</sub>

	SF <sub>6</sub>	Vacuum
Engineering	Same	Same
		✓
		✓
		✓
	✓	
		✓

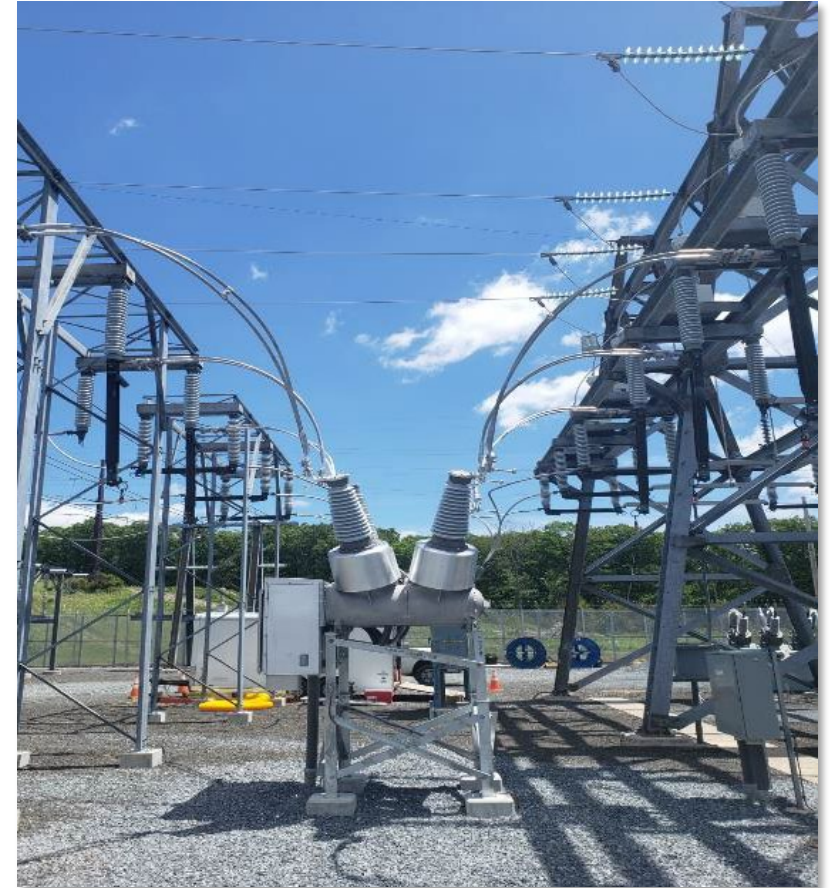


# Pilots / Strategy

Partnering with 3-vendors will have available Vacuum Circuit Breaker Development

## 2020 Pilots and Beyond

- 1<sup>st</sup> Vacuum CB on PPL EU Transmission System in June 2020
- 1<sup>st</sup> at 72.5kV Vacuum in PA!
- 2 installed to date , 1- more planned for Sep
- 25 - VCB's planned for 2021 at 72.5kV



# Collaboration with OEM

- Reliability Record
- The OEM 69 kV VCB has been on the market since 2007
- Through July 2020, 860 units were installed or under contract in North America
- Zero major failures have been recorded to date
- One operational failure due to a loss of vacuum

MTBF (Mean Time Between Failure)	
SF <sub>6</sub>	VCB
500 years/CB	6,289 years/CB

*\* from CIGRE and HTDS data*

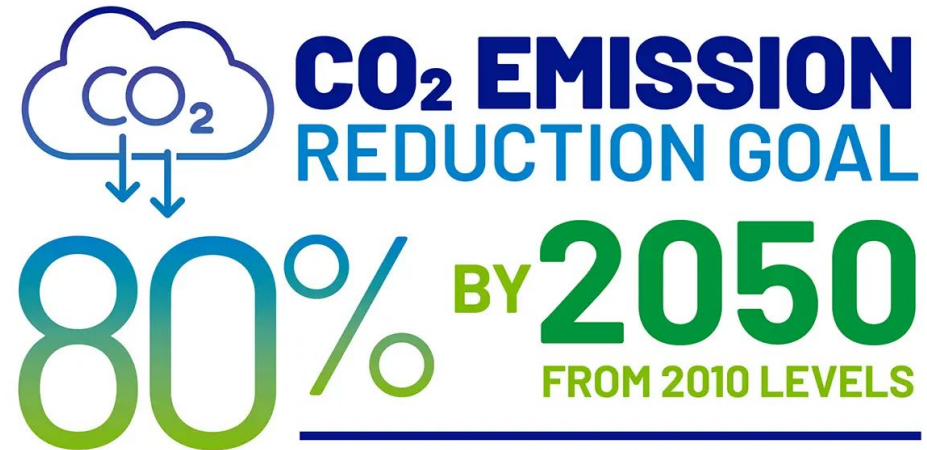
# Availability of VCB's

- Proven Technology Medium Voltage Availability
- Penetrating with multiple vendors at 72.5kV DTVCB (2020/2021)
- LVCB Vacuum availability ahead up to 145kV available for IEC markets
- GIS – Utilizing alternatives and Dry Air
- Alternative to SF<sub>6</sub>
- Availability for VCB DTVCB's:
  - 72.5kV: Available today
  - 115/145kV: 2021 to 2022
  - 245kV: Tentative 2024 to 2025





# Energy and Environmental Partnership



## Advance a cleaner energy future

Encourage responsible stewardship in partnership with our customers and stakeholders to have a sustainable environmental impact

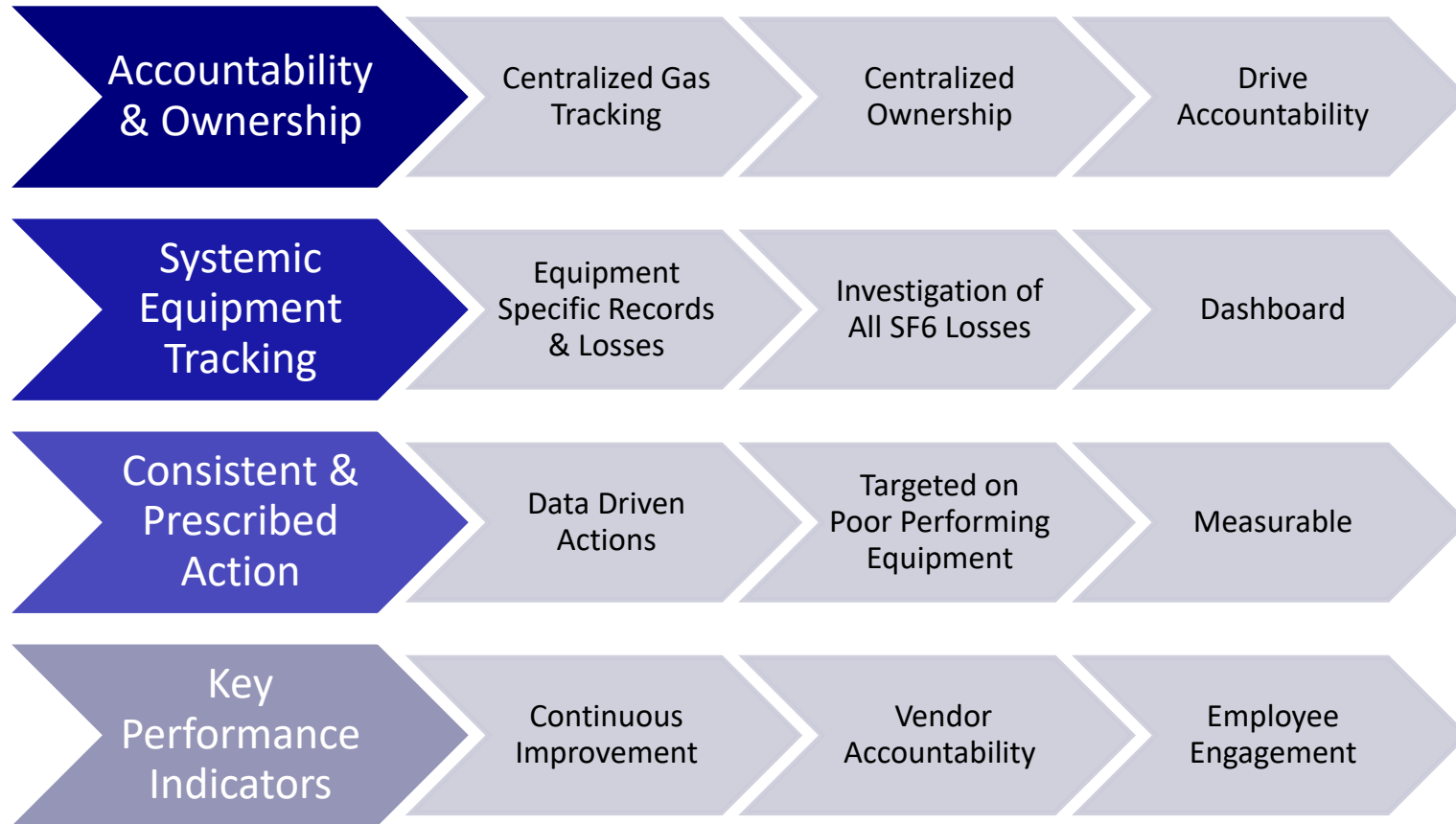


## Build tomorrow's energy infrastructure

Invest in tomorrow's energy infrastructure by developing a reliable, resilient and efficient grid that fosters continued progress and a cleaner energy future

# Accountability & Program Management

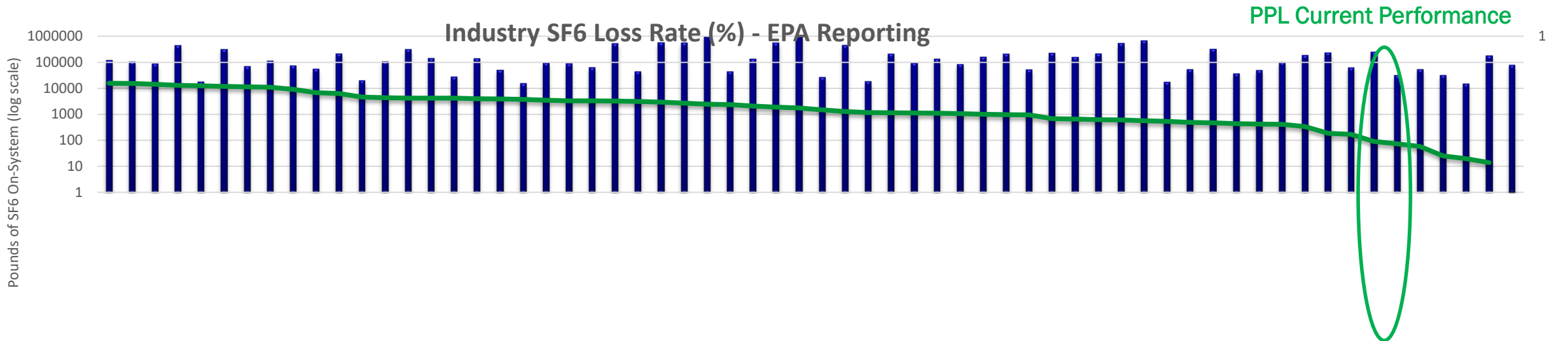
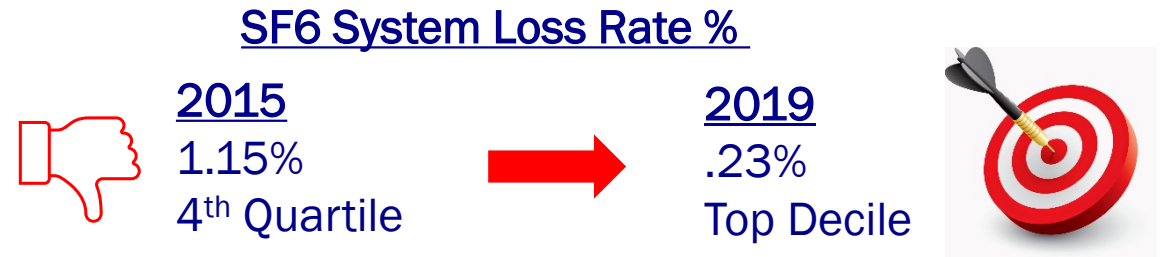
## SF6 Sustainability Program Principles



# Driving Results Through Continuous Improvement

## Benchmarking & Driving Results

- Utility Best Practices Sharing & Peer Engagement
- Key Performance Metrics
  - Pounds of SF6 System Lost
  - Leaks/Fills per Device
  - % SF6 Loss Rate
- Commitment to Goals





# SF<sub>6</sub> Free Alternative Medium and High Voltage Circuit Breakers: Vacuum Technology

Questions?



**Thank you!**

**SF<sub>6</sub> Emission Reduction Partnership for Electric  
Power Systems**

<https://www.epa.gov/f-gas-partnership-programs/electric-power-systems-partnership>

[SF6Partnership@epa.gov](mailto:SF6Partnership@epa.gov)

**Get involved – contact for opportunities to  
collaborate!**

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