Warm Gas Cleanup and CCS Demonstration at Tampa Electric's Polk Power Station

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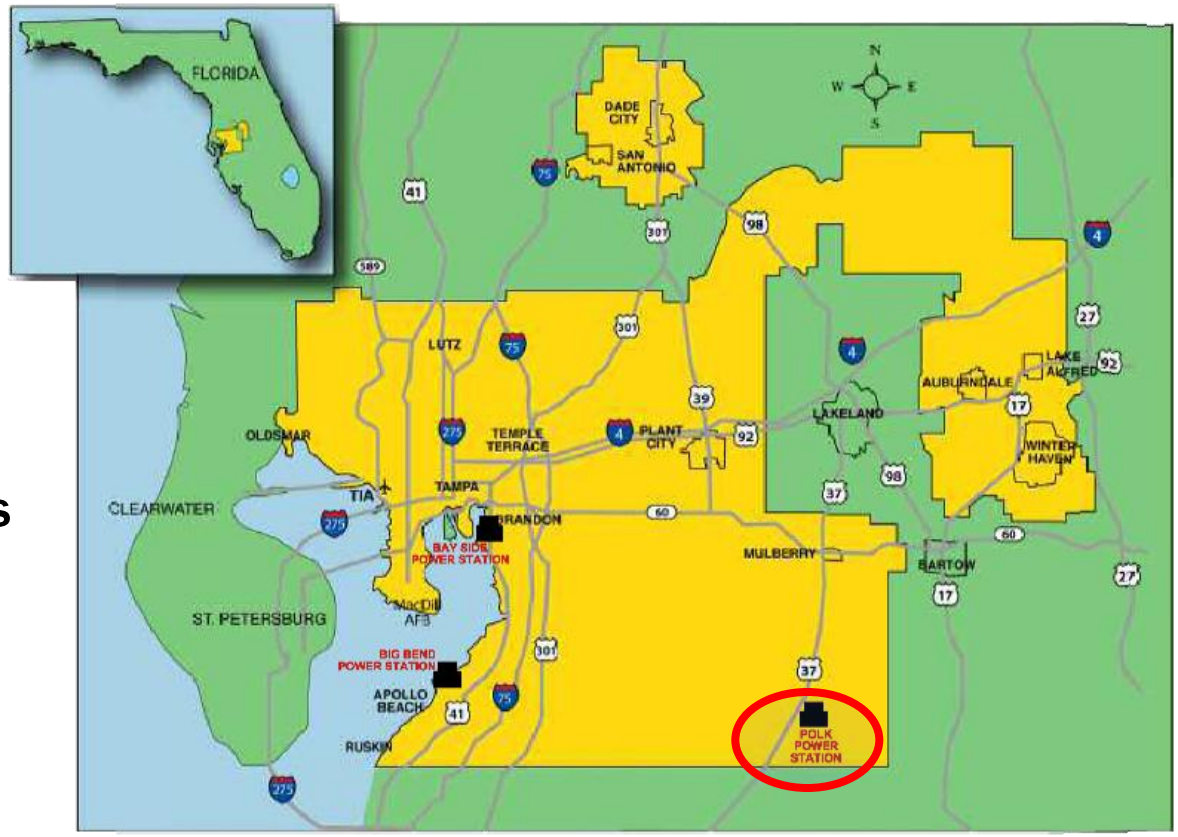
About Tampa Electric

- Investor owned utility
- 2,000-square-mile service area
- More than 645,000 residential, commercial, and industrial customers
- Five electric generating stations with a total capacity of 4,800 MW



- Polk Power Station (PPS) – Polk 1 in commercial service Sep 1996
  - Site – 4,348 Acres (2,837 acres east of SR 37, power block ~ 340 acres)
  - Unit 1 – 260 MW IGCC; Units 2-5 – 165 MW SC; 920 MW total

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RTI International

- Established 1958 as collaboration between state government, area universities and business leaders
- Mission: to improve the human condition by turning knowledge into practice
- One of the world's leading research institutes
- FY2010 Research revenue: $760 million
- Staff: 4,200

Project Origins and Synergies

- DOE cooperative agreement in place (2009) to demonstrate RTI's Warm Gas Cleanup (WGC) technology at Polk Power Station
- Common goal of Tampa Electric, RTI and DOE to demonstrate CCS
- Existing WGC project slipstream size would allow for sequestration of up to 300,000 tons of CO_2
- Tampa Electric in the process of implementing a waste water re-use project at the Polk site which included construction of two deep injection wells for disposal of RO reject
- One injection well could be dedicated for CO_2 injection during the desired operation period of the WGC/CCS project
- Substantial geologic evaluations have been completed which indicate that the geology beneath the site is suitable for permanent CO_2 sequestration

Combined WGC & CCS Demonstration

- DOE support for the addition of CCS to the existing WGC project was announced in September 2010
- Warm Syngas Clean-Up
  - remove sulfur and trace contaminants (sulfur to single digit ppm)
- Add shift reactor (sweet shift) and syngas cooling
- Add CO_2 removal using aMDEA
  - low capital cost and energy use
  - capture up to 90% of available carbon in syngas slipstream
- Add CCS
  - sequester up to 300,000 tons CO_2
  - Utilize one of two injection wells for demonstration period

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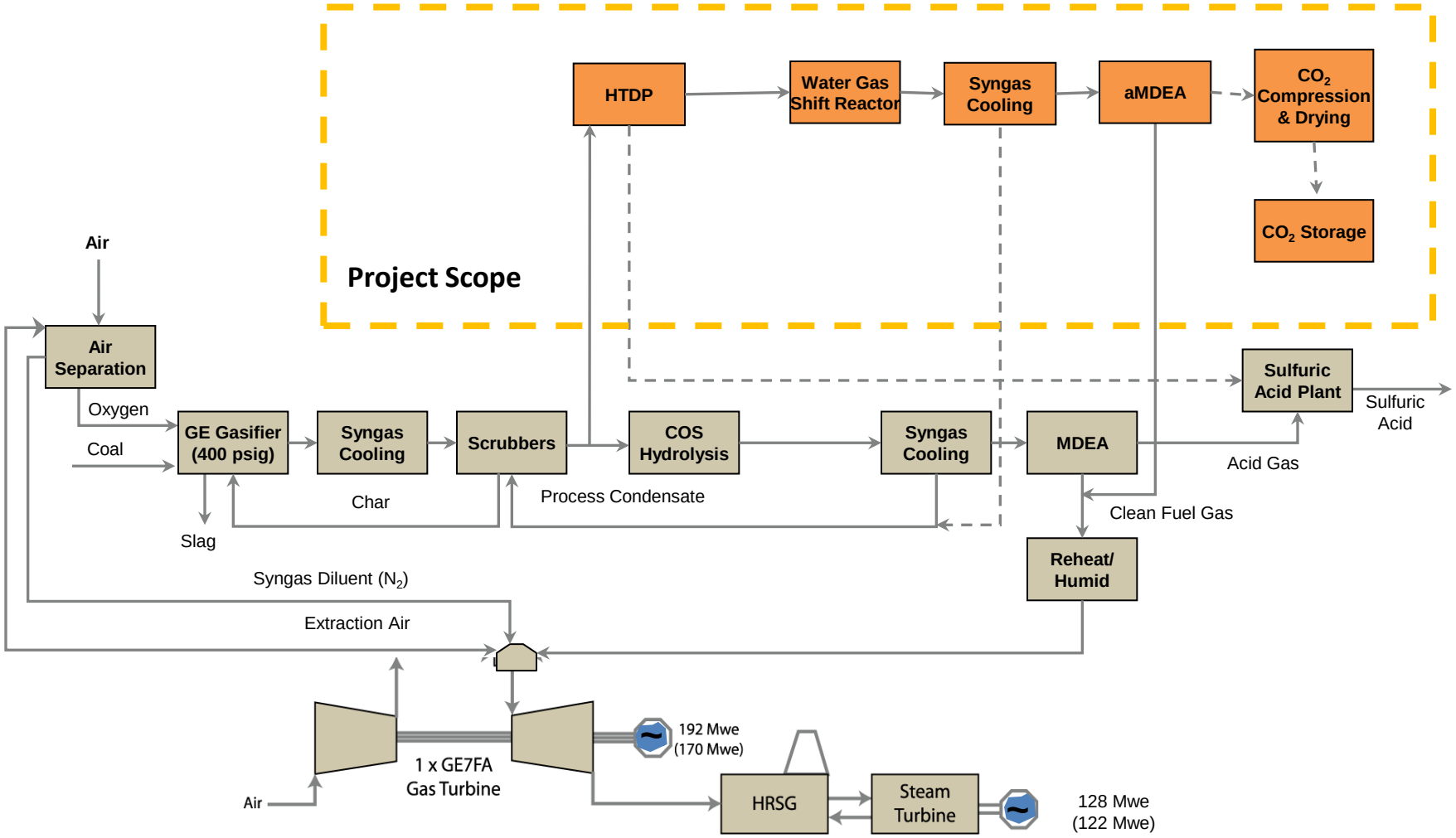
Integration of Syngas Cleaning and CCS Systems at Tampa Electric



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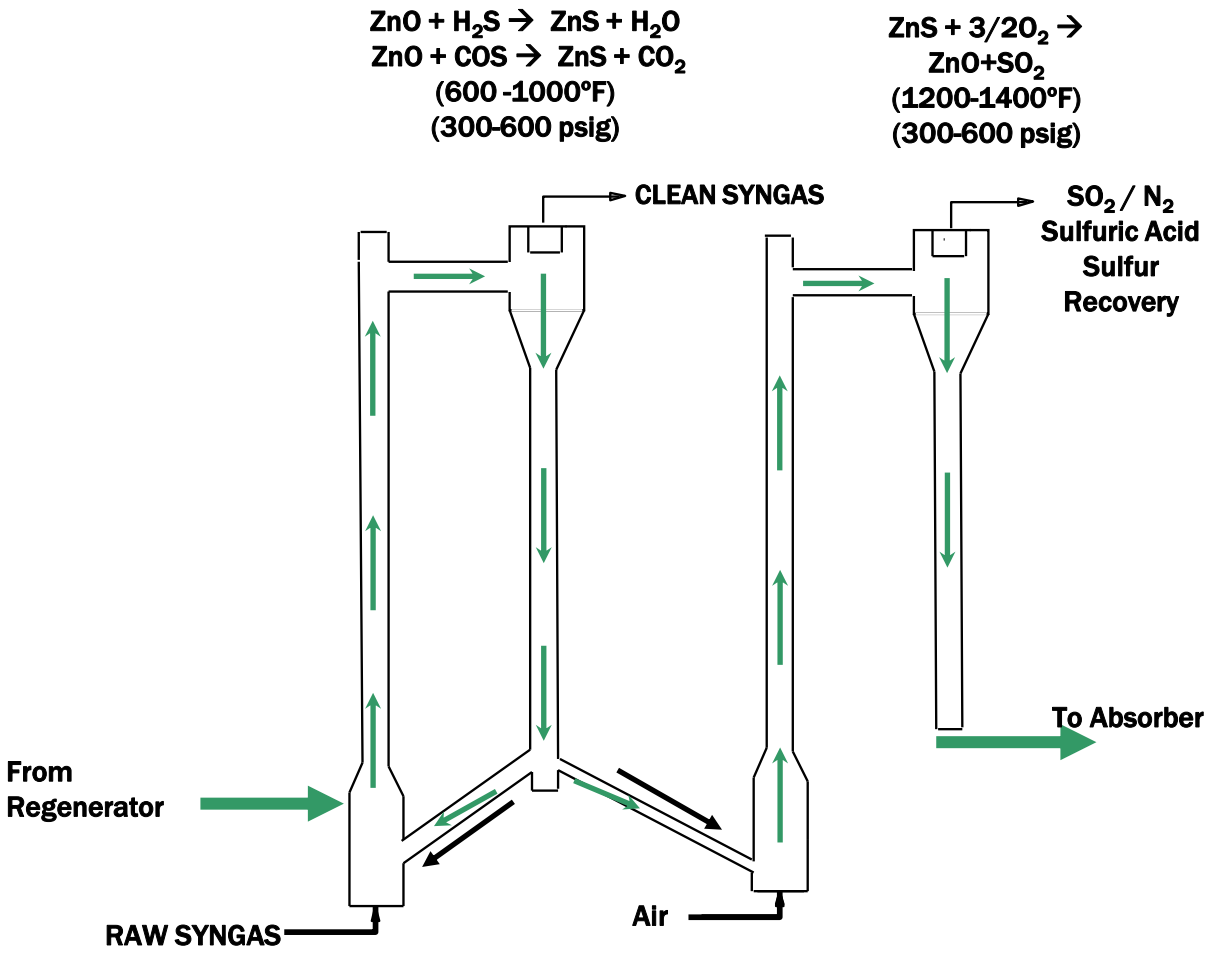
Transport Desulfurization Reactor System



High Temperature Desulfurization Process (HTDP)

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Warm Gas Cleanup Benefits

- Comparison of RTI/Eastman Warm Gas Clean-up technologies with conventional syngas clean-up technologies performed by Nexant:
  - 600 MW case study – GE Reference plant as a base case
  - Increase efficiency by 3.6 points HHV
  - Dispatch 56 MWe more power
  - Reduce CAPEX by $264/kW
  - Reduce COE by 0.69 ¢/kWh
  - Reduce makeup water consumption by 25%
  - Reduce wastewater by 60%
- Independent analysis performed by Noblis confirmed these results (http://www.netl.doe.gov/technologies/coalpower/gasification/pubs/market.html)

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Project Objectives

- Warm Syngas Clean-up
  - Design, construct, commission, and operate a warm syngas cleaning demonstration system
  - Establish relevant commercial operating experience
  - Establish RAM (reliability, availability and maintenance) targets
  - Mitigate design and scale up risk for commercial plant
  - Obtain 8,000 hours of operations
- Carbon Capture and Sequestration
  - Sequester 300,000 tons of CO_2/year
  - Use of conventional capture technology (activated amine)
  - Demonstrate CCS in Florida using regionally extensive Lawson formation

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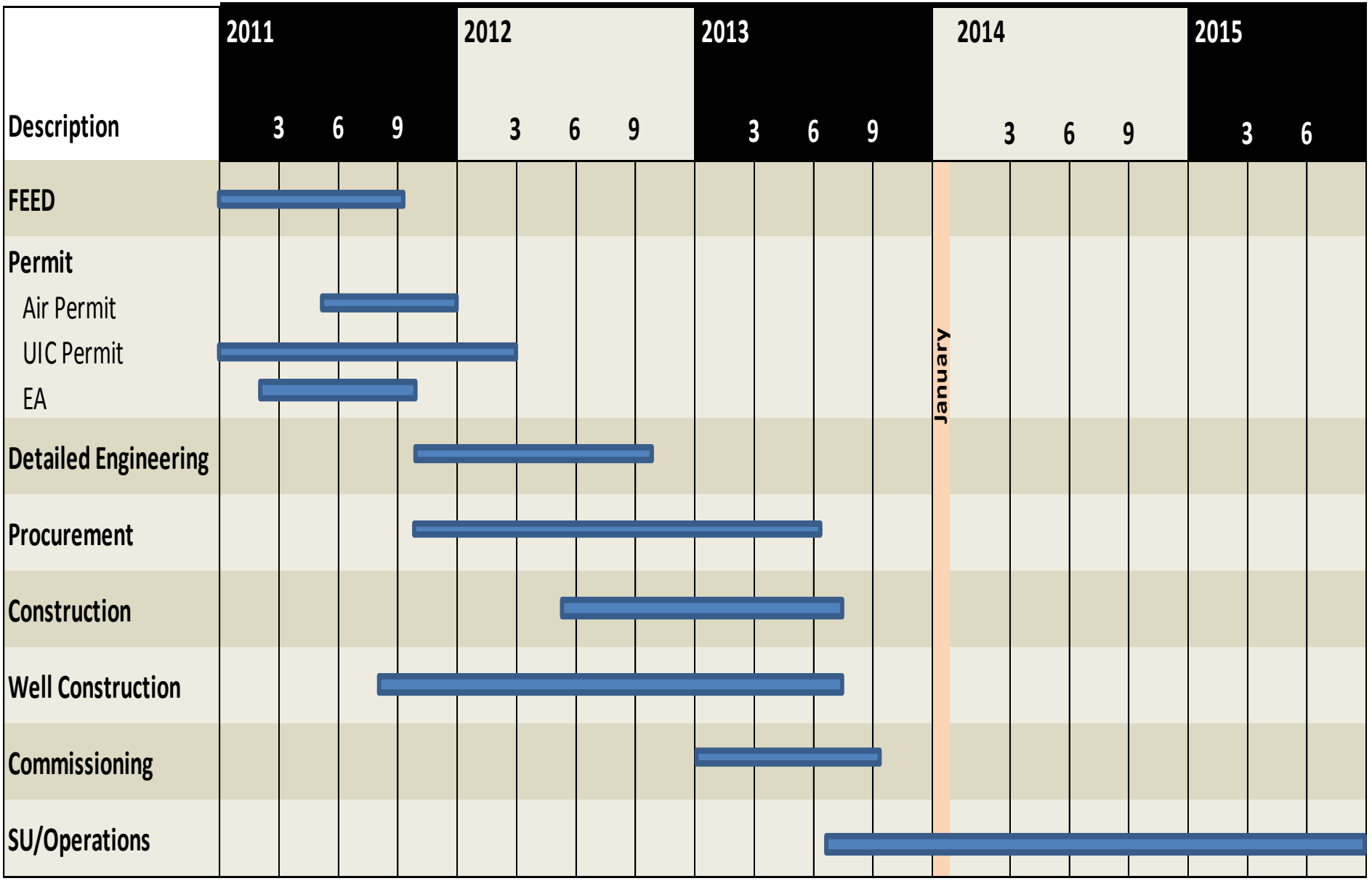
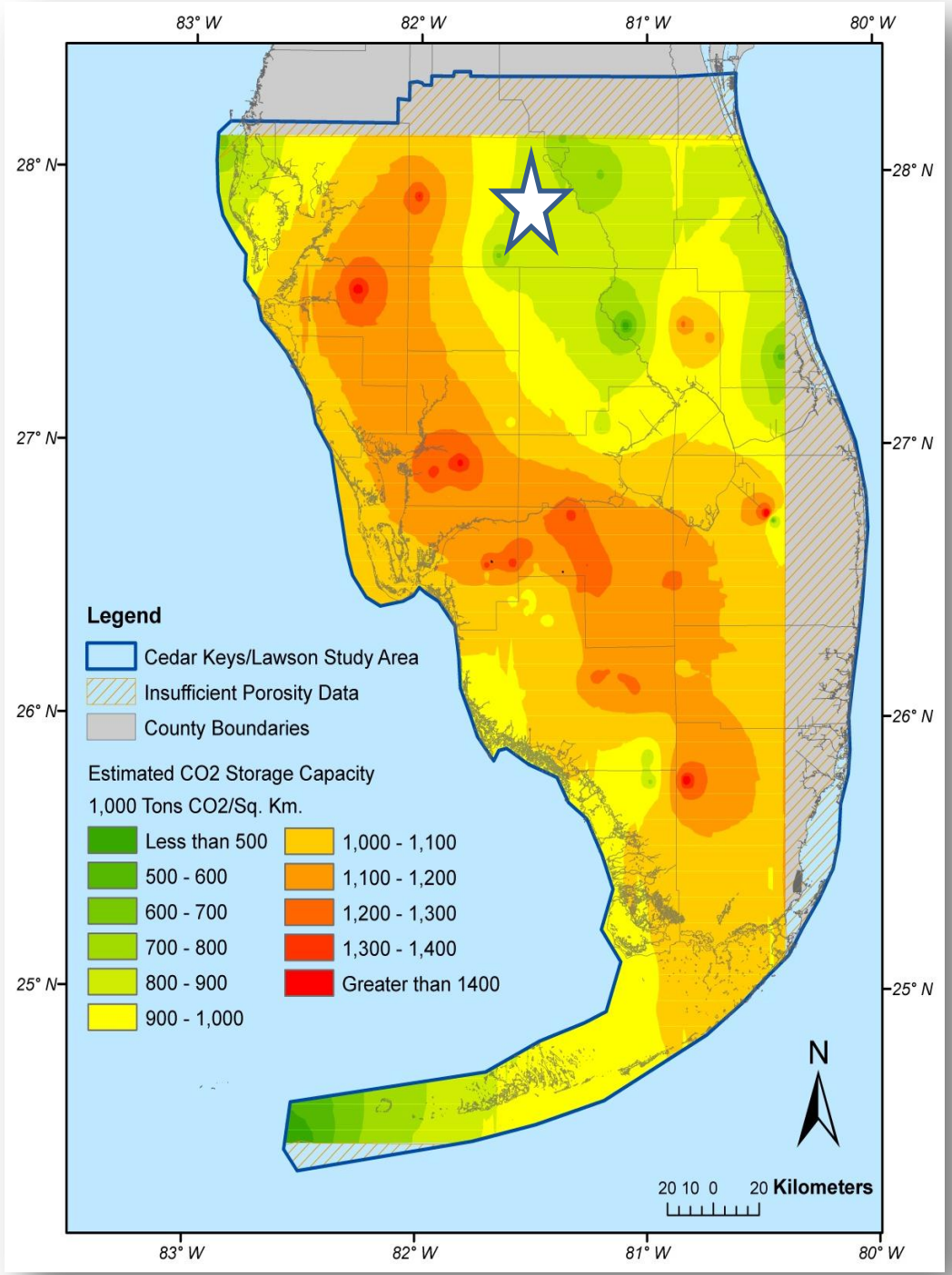
Project Schedule



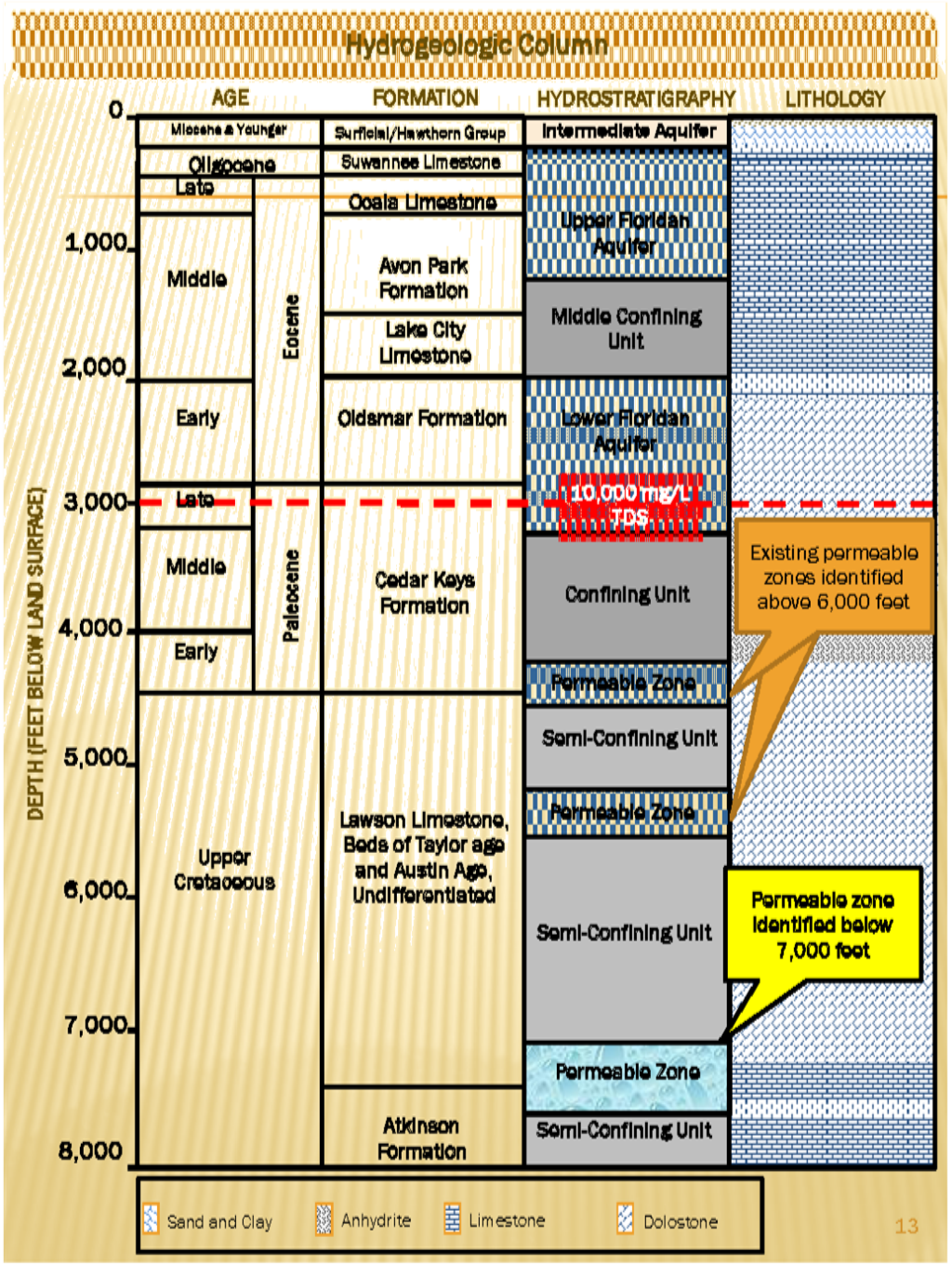


- Cedar Keys-Lawson injection zone CO_2 storage potential (tons/km^2)
- A large area of southwest and south-central Florida has storage capacities >1,000,000 CO_2 tons/km^2
- Region CO_2 Emissions
  - 108 sources = 143 M tons CO_2/yr
- Region CO_2 Storage Potential
  - 15.8 – 216.9 Gtons storage
  - 110 – 1500 years of storage

Source USF

Polk Site Geology

- Excellent confinement
  - Approximate 1100’ interval comprised largely of anhydrite (2850’ – 4000’)
  - Very low permeability (standard test protocols would take months/years)
- Injection zone of over 3800’ open borehole (from 4125’ to 8000’)
  - Baffled arrangement due to semi-confining layers between permeable layers
  - Excellent for CO_2 injection



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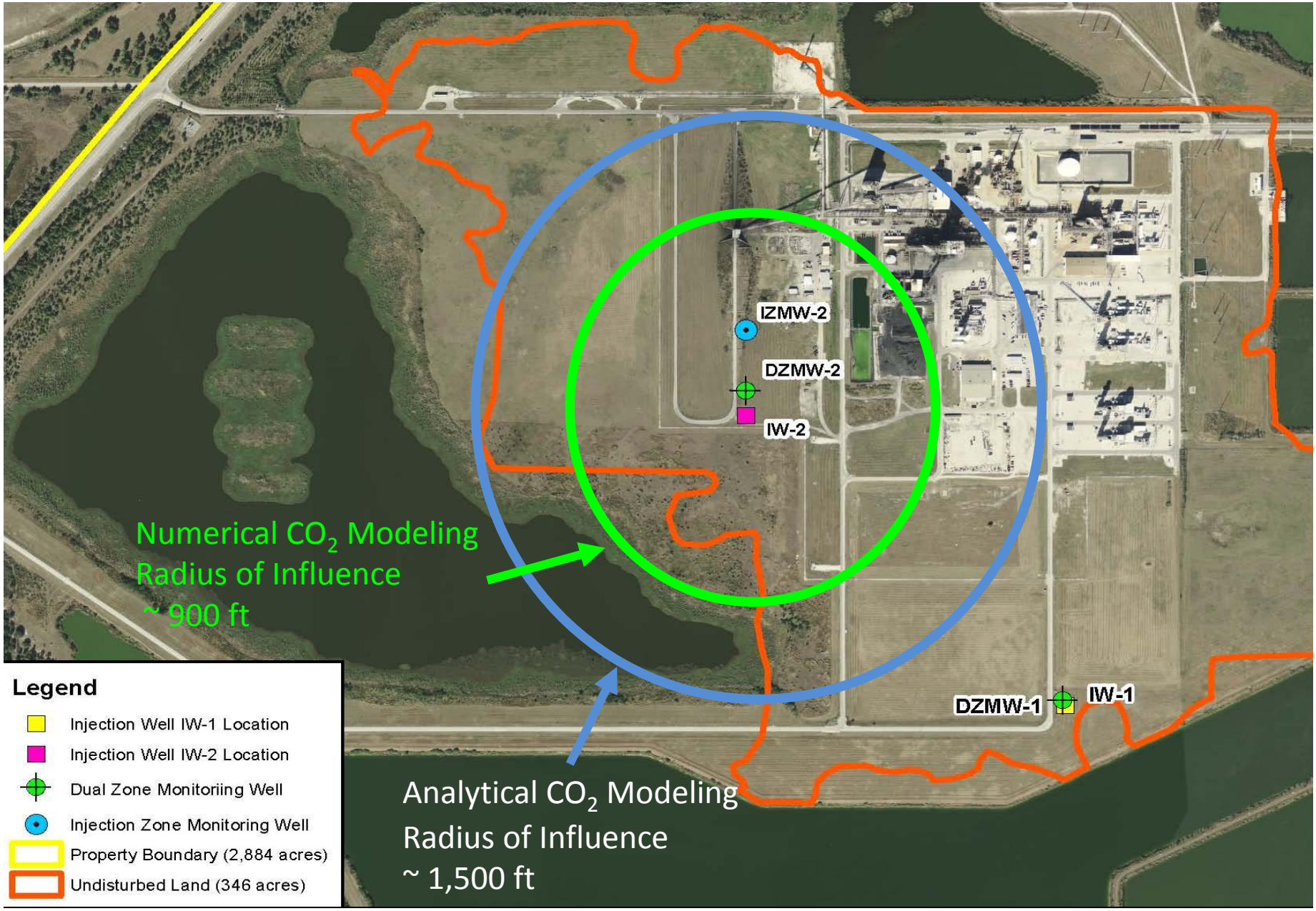
TEC PPS Site Map and UIC Well Locations

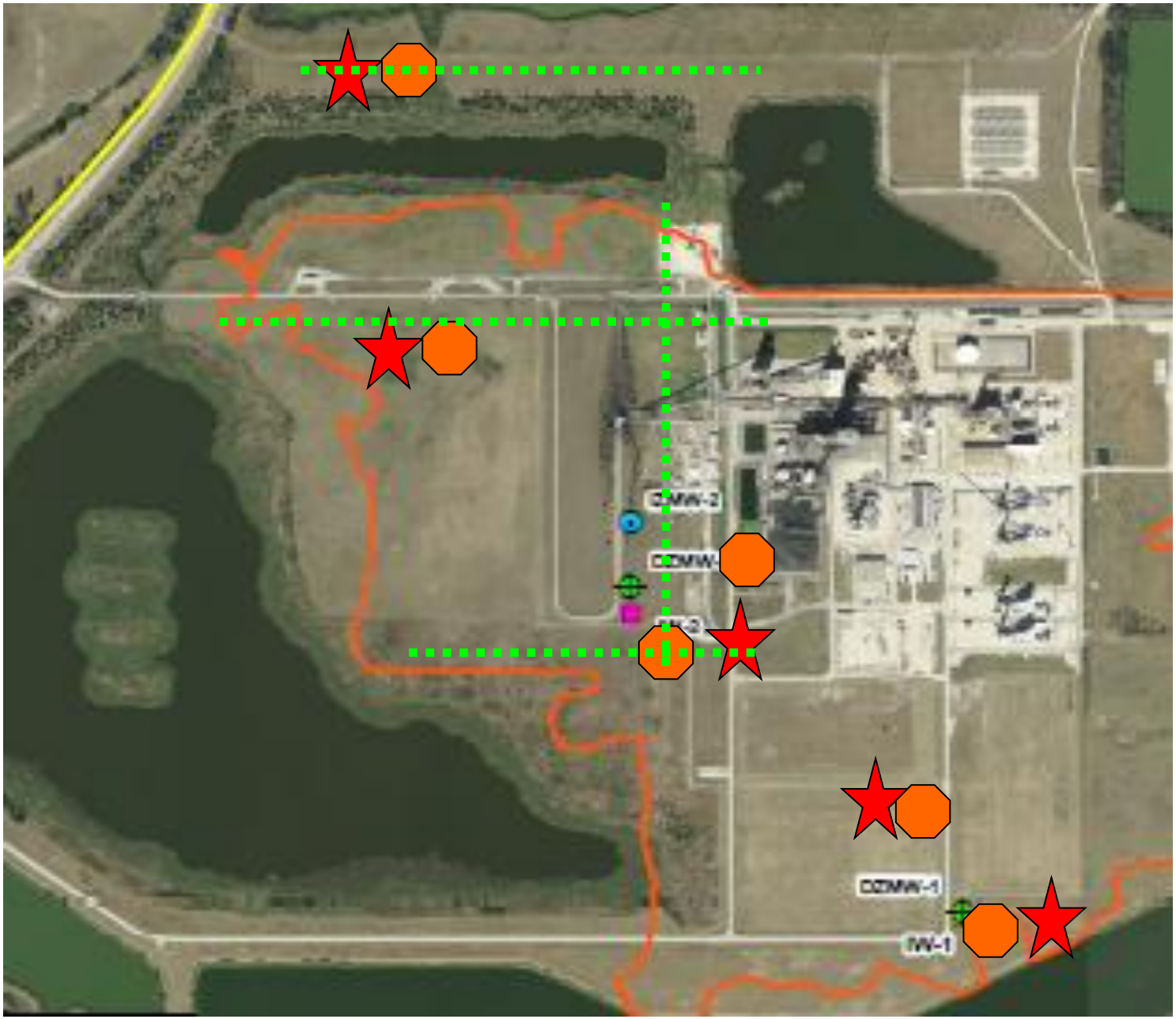


MVA Monitoring Locations

GPS/InSAR Monitoring

Vadose Zone Shallow GW Monitoring

Vertical Seismic Profiles



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CO_2 Storage & Trapping Mechanisms
(IPCC 2005)

Physical Storage & Trapping

- Stratigraphic & Structural – CO_2 is contained by geological features
- Hydrodynamic – CO_2 is transported within saline formation fluids based on injection pressure and/or natural hydraulic gradients
- Residual CO_2 Trapping – As CO_2 migrates some is retained in pore space by capillary forces

CO_2 Storage & Trapping Mechanisms
(IPCC 2005)

Geochemical Storage & Trapping

- Solubility Trapping - As CO_2 migrates through the saline formation, some of the supercritical fluid reacts with and dissolves within the saline water. This is a long-term, stable and desirable trapping mechanism.

- Mineral Trapping – As the dissolved CO_2 reacts with the carbonate formation minerals, new and different carbonate minerals will precipitate out of solution and become part of the subsurface formation. This is a long-term, stable and desirable trapping mechanism.

Polk CO_2 Injection Modeling

- Injection well 2 will be used for CO_2 injection for approximately 18 months followed by waste water injection
- Modeling was done to understand how CO_2 would behave with waste water “flush” expecting there might be issues
- Results actually showed a surprising benefit
- Typical sequestration schemes have CO_2 injected and then left undisturbed – movement and resulting reactions are very slow
- Waste water follow up dramatically increased the rate of dissolution into brine and mineral reactions
- Model results suggest complete permanent trapping in less than five years!
- If confirmed, rapid trapping would mitigate long term liabilities for sequestration

CO_2 Trapping Processes

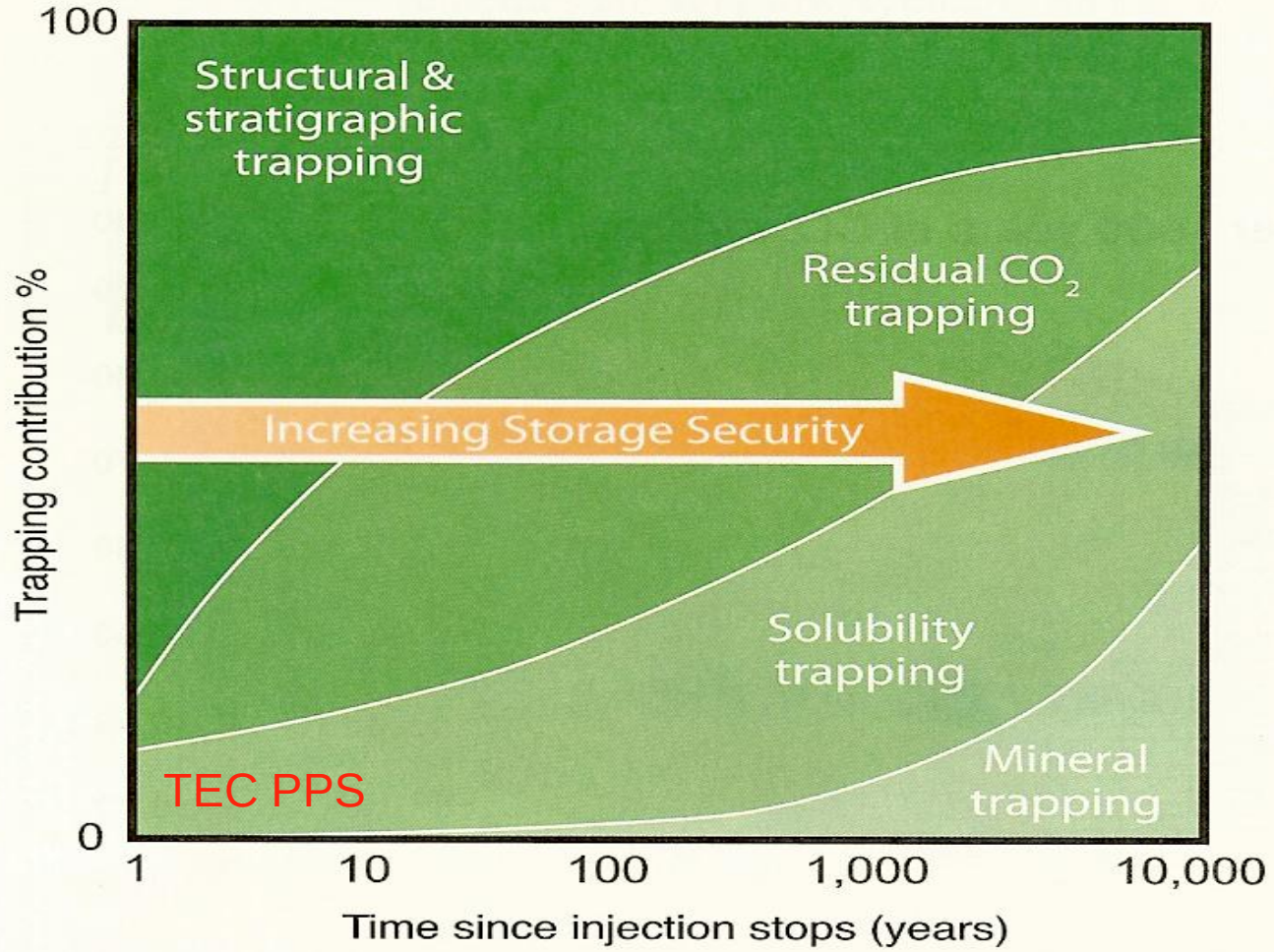

Figure 5.9 Storage security depends on a combination of physical and geochemical trapping. Over time, the physical process of residual CO_2 trapping and geochemical processes of solubility trapping and mineral trapping increase.

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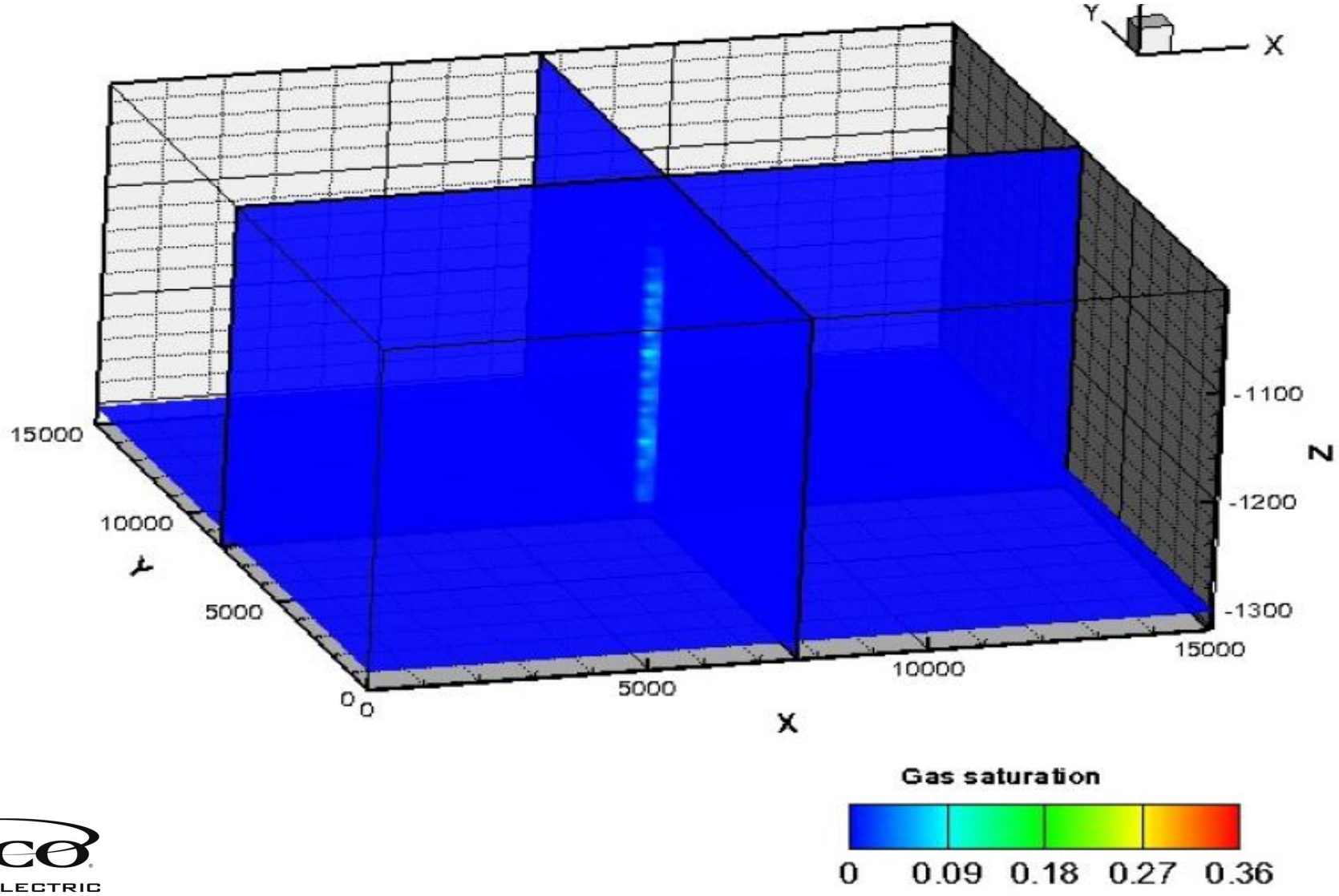
CO_2 Saturation After 1 Year of CO_2 Injection at IW2 at 300,000 Tons Per Year



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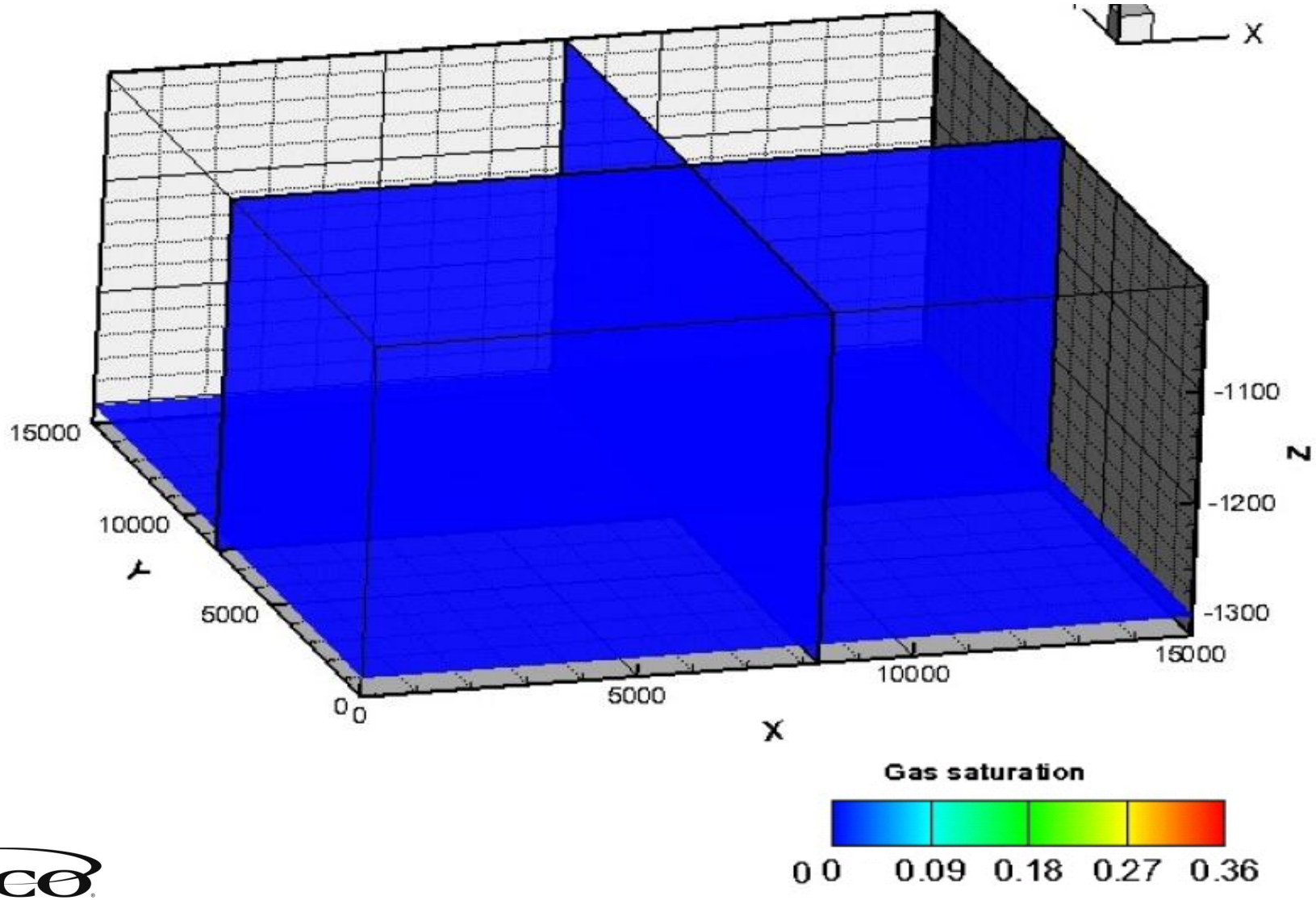
CO_2 Saturation After 1 Year of Wastewater Injection at IW2 CO_2 Plume has Dissolved Into Brine and Wastewater



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Summary

- Successful demonstration of warm gas cleanup technology has the potential to reduce CAPEX, increase efficiency, reduce emissions and reduce COE of IGCC plants.
- WGC for deep sulfur removal combined with conventional amine for CO_2 removal should provide high performance at low cost.
- CCS project at Polk Power Station will be first large scale demonstration at an operating IGCC plant.
- Carbon sequestration at Polk Power Station will be the first for Florida and first to use the regionally extensive Lawson formation.
- Unique application of CO_2 injection followed by waste water injection shows promise for very rapid trapping.
- This strategy could potentially be applied to future sequestration efforts.

Thank you for your attention

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