History of the Texas Interconnection

Joel Mickey
Senior Director,
Market Design & Operations

Standards to Promote Interoperability: Interconnection Code Compliance & Corrective Actions

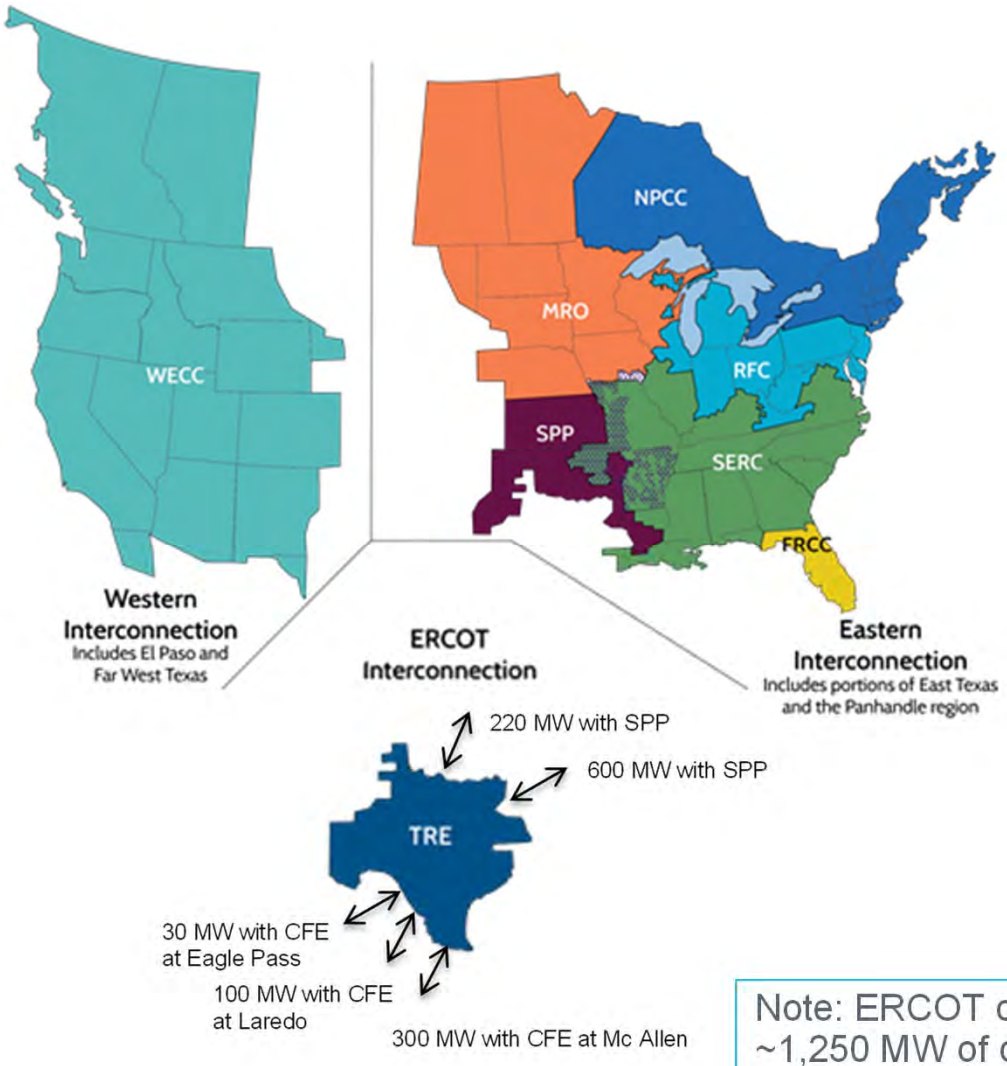
U.S.-Africa Clean Energy Standards Program

Kigali, Rwanda
Oct. 1, 2018

Topics

- North America Power Grids
- ISOs and RTOs
- ERCOT
- Evolving Grid
- Interconnection Rules

The ERCOT Region



The interconnected electrical system serving most of Texas, with limited external connections

90% of Texas electric load; 75% of Texas land

73,308 MW peak, July 19, 2018

More than 46,500 miles of transmission lines

570+ generation units

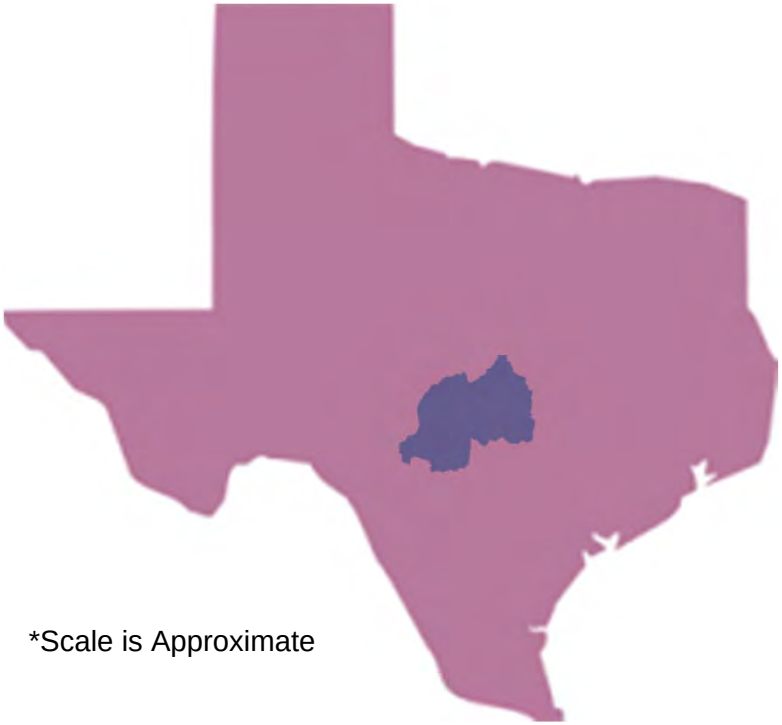
Note: ERCOT connections to other grids are limited to ~1,250 MW of direct current (DC) ties, which allow control over flow of electricity

HM2

Slide 3

HM2 note that the ERCOT website says 600+
Hilliard, Marie, 9/27/2018

Comparing Rwanda to Texas

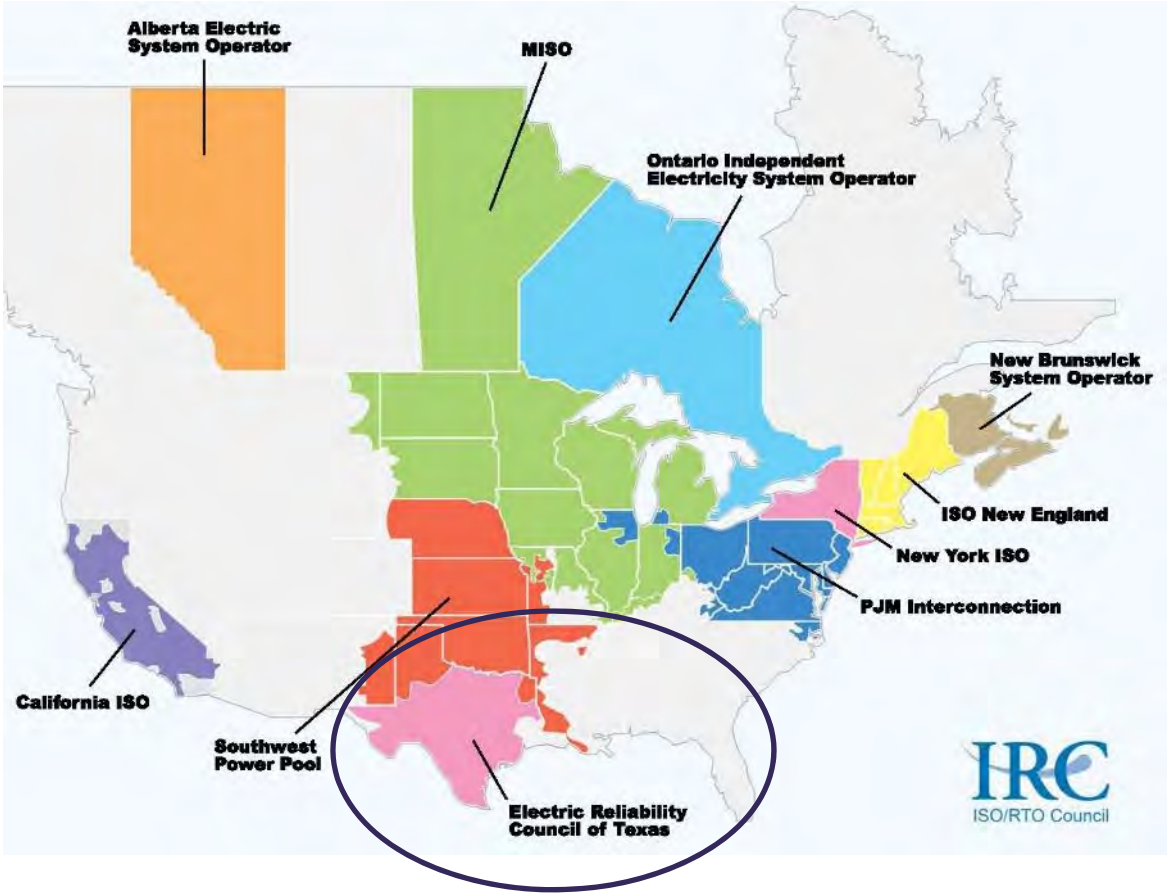


*Scale is Approximate

	Rwanda	Texas
Area	>10,000 mi^2	>200,000m mi^2
Current Customers	>3.5 million customers	> 25 million customers
Transmission Lines	unknown	>4,650 miles
Generation		600+ generation units
Generation Mix	Hydroelectric: 53% Thermal: 47%	Thermal: 77% Wind: 21% Other: 2%
Installed Capacity	209 MW	>100,000 MW *

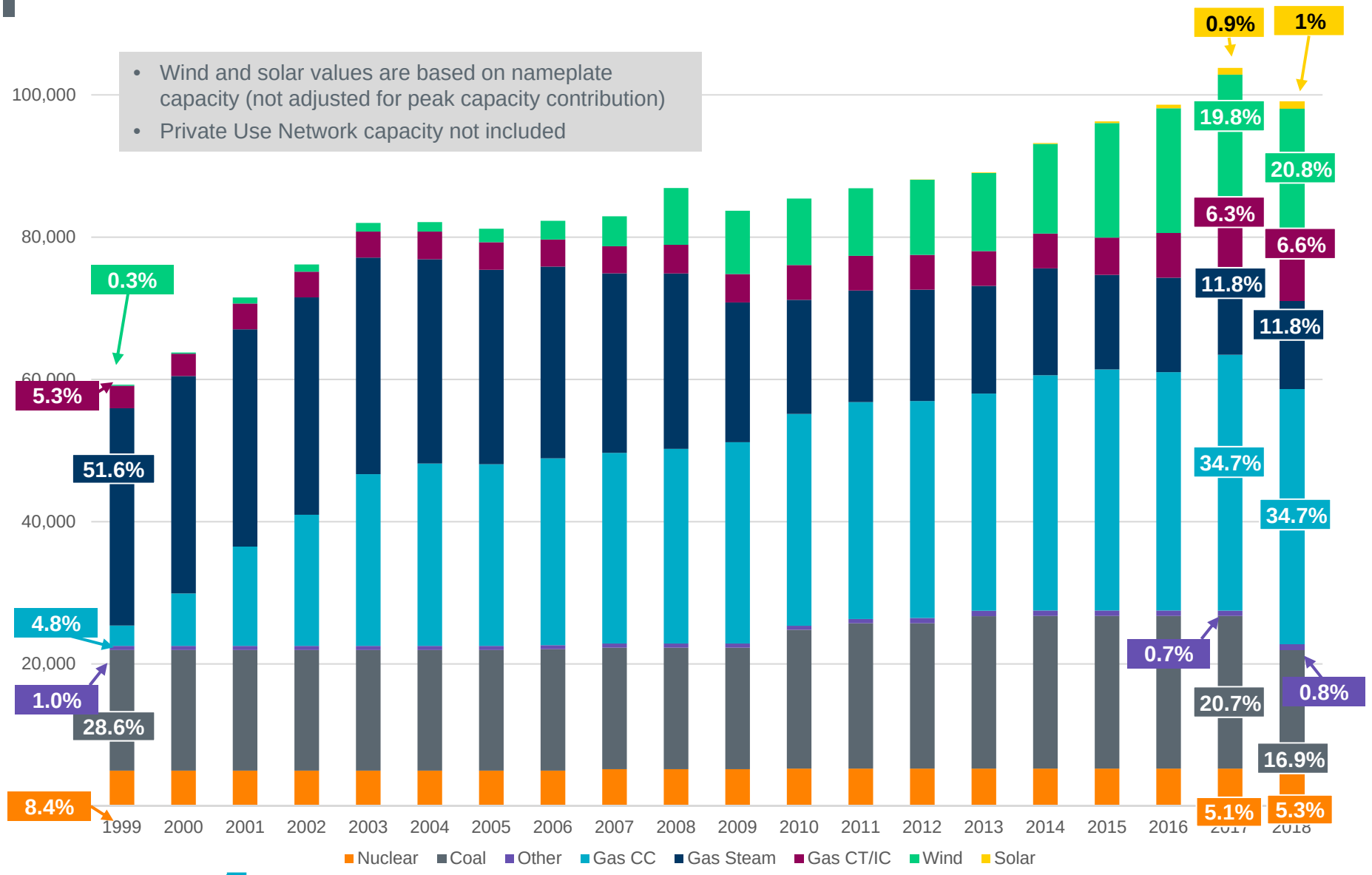
*This number uses installed capacity for intermittent resources; not peak capacity contribution

North American ISOs and RTOs

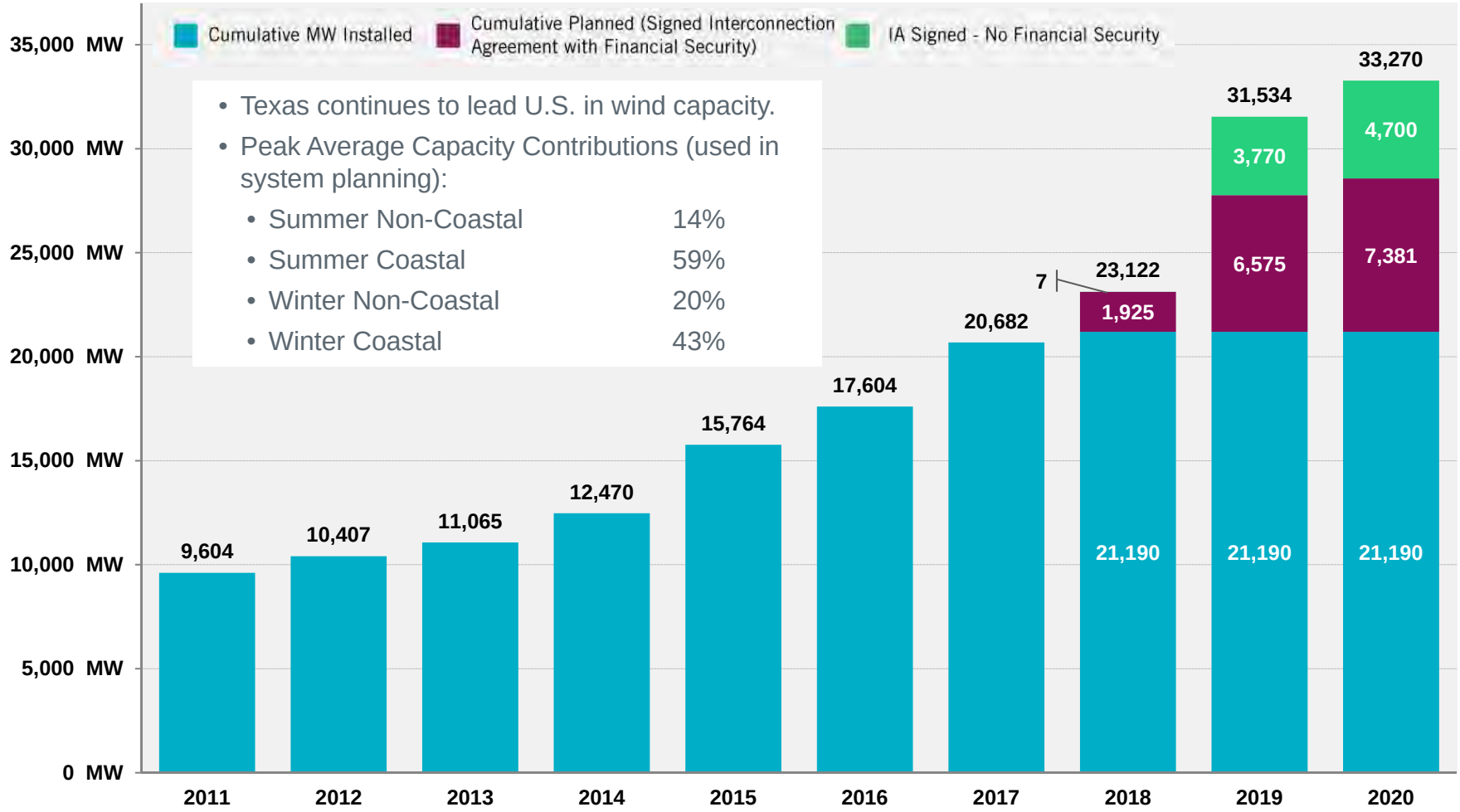


Independent System Operators and ***Regional Transmission Organizations*** are the 'air traffic controllers' of the bulk electric power grids *(69kV and up)*

ERCOT Installed Capacity (1999-2018)



Wind Generation Capacity – August 2018

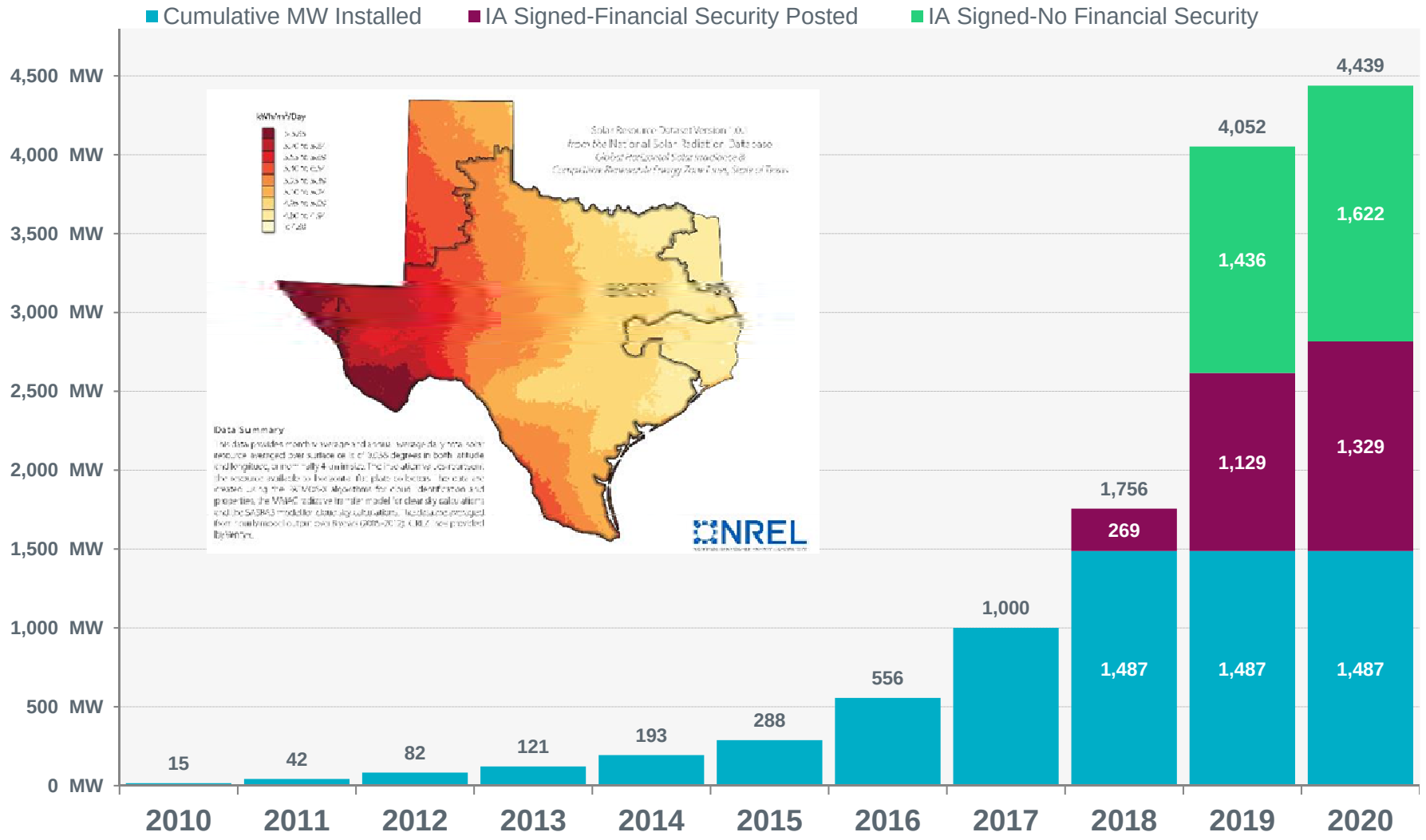


The data presented here is based upon the latest registration data provided to ERCOT by the resource owners and can change without notice. Any capacity changes will be reflected in current and subsequent years' totals. Scheduling delays will also be reflected in the planned projects as that information is received. This chart reflects planned units in the calendar year of submission rather than installations by peak of year shown.

Financial security posted for funding interconnection facilities does not include CREZ security deposits, which are refunded to the Interconnecting Entity when an IA is signed.

As of August 31, 2018

Utility Scale Solar Generation Capacity – August 2018



The data presented here is based upon the latest registration data provided to ERCOT by the resource owners and can change without notice. Any capacity changes will be reflected in current and subsequent years' totals. Scheduling delays will also be reflected in the planned projects as that information is received. This chart reflects planned units in the calendar year of submission rather than installations by peak of year shown.

As of August 31, 2018

Regulatory Environment

Federal

DOE
Department of Energy

Responsible for the national energy program

Propose and advocate policies and programmatic goals for economic welfare

FERC
Federal Energy Regulatory Commission

Regulates the sale and transmission of electricity in interstate commerce

Oversees development and enforcement of Electric Reliability Standards

For Texas:

Subject to reliability
Not for markets

State

PUCT
Public Utility Commission of Texas

Oversees competitive electrical markets

Oversees ERCOT budget and operations

Enforces statutes and rules for electric industry

Regulatory Environment

FERC
Federal Energy Regulatory Commission

Reliability Oversight

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Reliability Standards

TEXAS RELIABILITY ENTITY™

Compliance

ERCOT NERC registrations-
BA, RC, PA, RP, TOP, TSP

The Texas Interconnected System

During WW2, the 10 independent power grids interconnected so they could send their excess power to the coast for heavy manufacturing industry to support the war effort

Once connected, they formed TIS, Texas Interconnected System

Operating guides were produced to dictate how the control areas would operate as one

These control areas soon realized other benefits from being connected

Benefits of the Interconnection

Increased reliability

Ability to share reserves

Better Reactive control

Lower costs to produce power

Increased flexibility to integrate renewable and intermittent sources

The 1965 Northeast Blackout

"All the News That's Fit to Print"

The New York Times.

LATE CITY EDITION

VOL. CXV ... No. 39,552 NEW YORK, WEDNESDAY, NOVEMBER 10, 1965 TEN CENTS

POWER FAILURE SNARLS NORTHEAST; 800,000 ARE CAUGHT IN SUBWAYS HERE; AUTOS TIED UP, CITY GROPES IN DARK

To Our Readers

Johnson Restates Goals in Vietnam

G.I.'s Score Big Victory

Vietcong Force Almost Wiped Out by U.S. Airborne Unit

Snarl at Rush Hour Spreads Into 9 States

10,000 in the National Guard and 5,000 Off-Duty Policemen Are Called to Service in New York

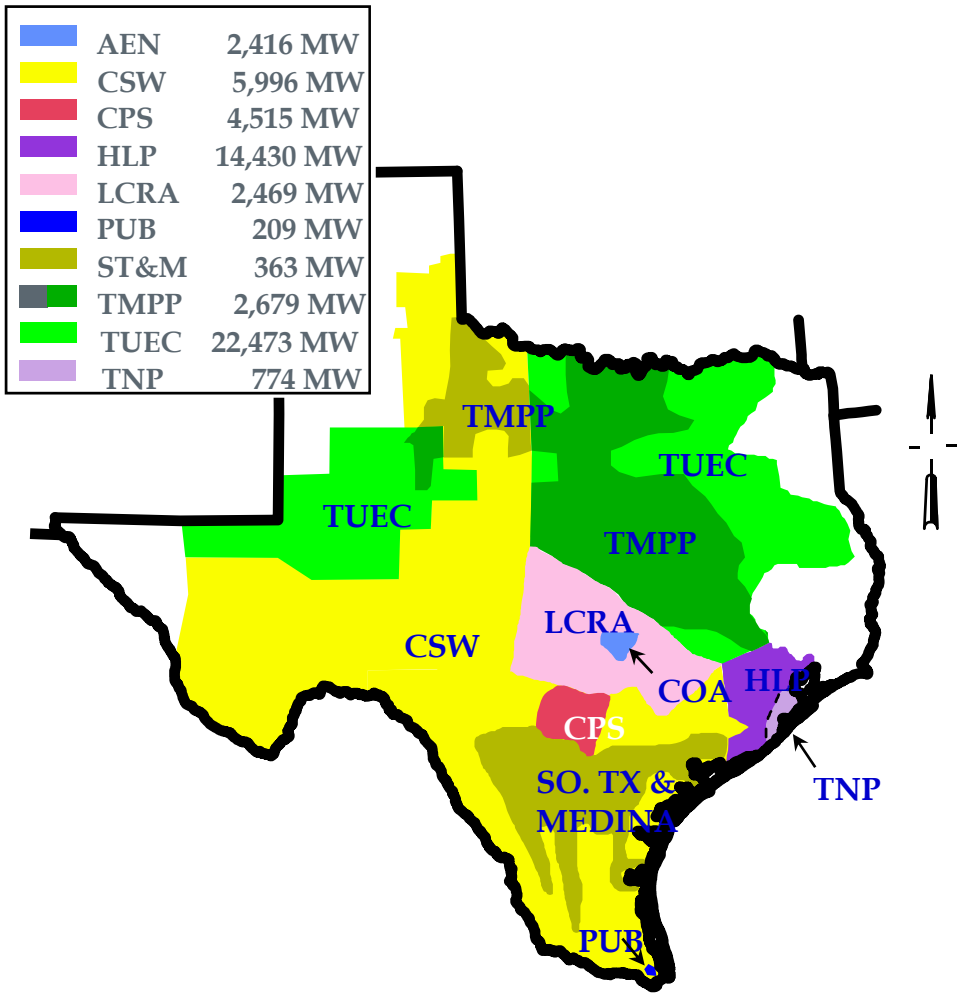
U.S. Orders An Inquiry

City's Glitter Goes But Not Its Poise

Food Is Sent To Subways

- On November 9, 1965 almost 30 million people in the northeastern United States lost power
  - It was the largest blackout in US history.
- Utilities responded to this event by voluntarily creating the National Electric Reliability Council
- After several name changes, today it is the North American Electric Reliability Corporation (NERC)
- In 1970 TIS joined NERC and became one of NERC's ten regional reliability areas
- The TIS renamed itself: ERCOT – the Electric Reliability Council of Texas

Vertically-integrated utilities



Note: Some areas were certificated to more than one utility. And areas are approximate.

- Prior to 1996, the ERCOT Region was operated by 10 separate Control Area Utilities
  - Owned most generation and transmission
  - Controlled access to the grid
- Control Areas did all transaction scheduling and staffed the committees that established the operating and business rules
- Load captive to their utility

Vertically-integrated utilities (through 1995)

Captive customer base

Multiple control areas with limited power flows between utilities

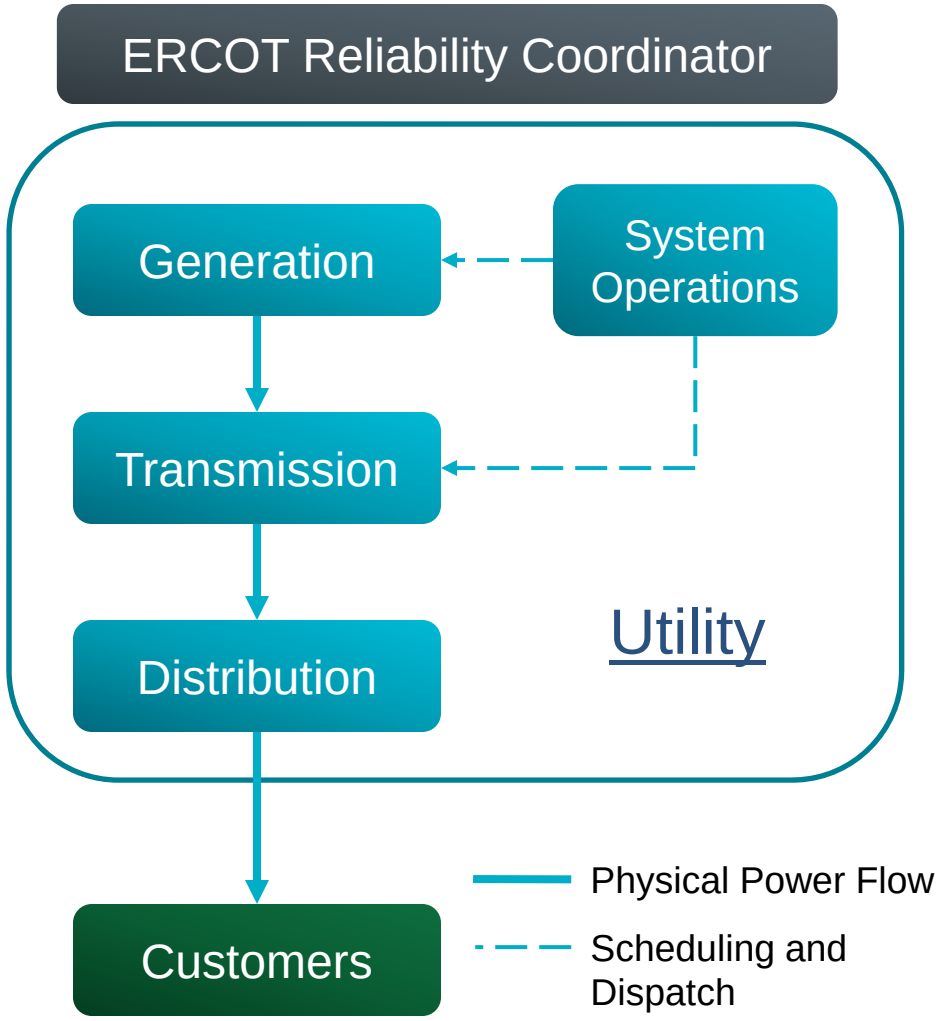
Regulated rate of return

Regulated price for customers
Approved through “rate case”
Based on utility’s cost plus reasonable profit margin

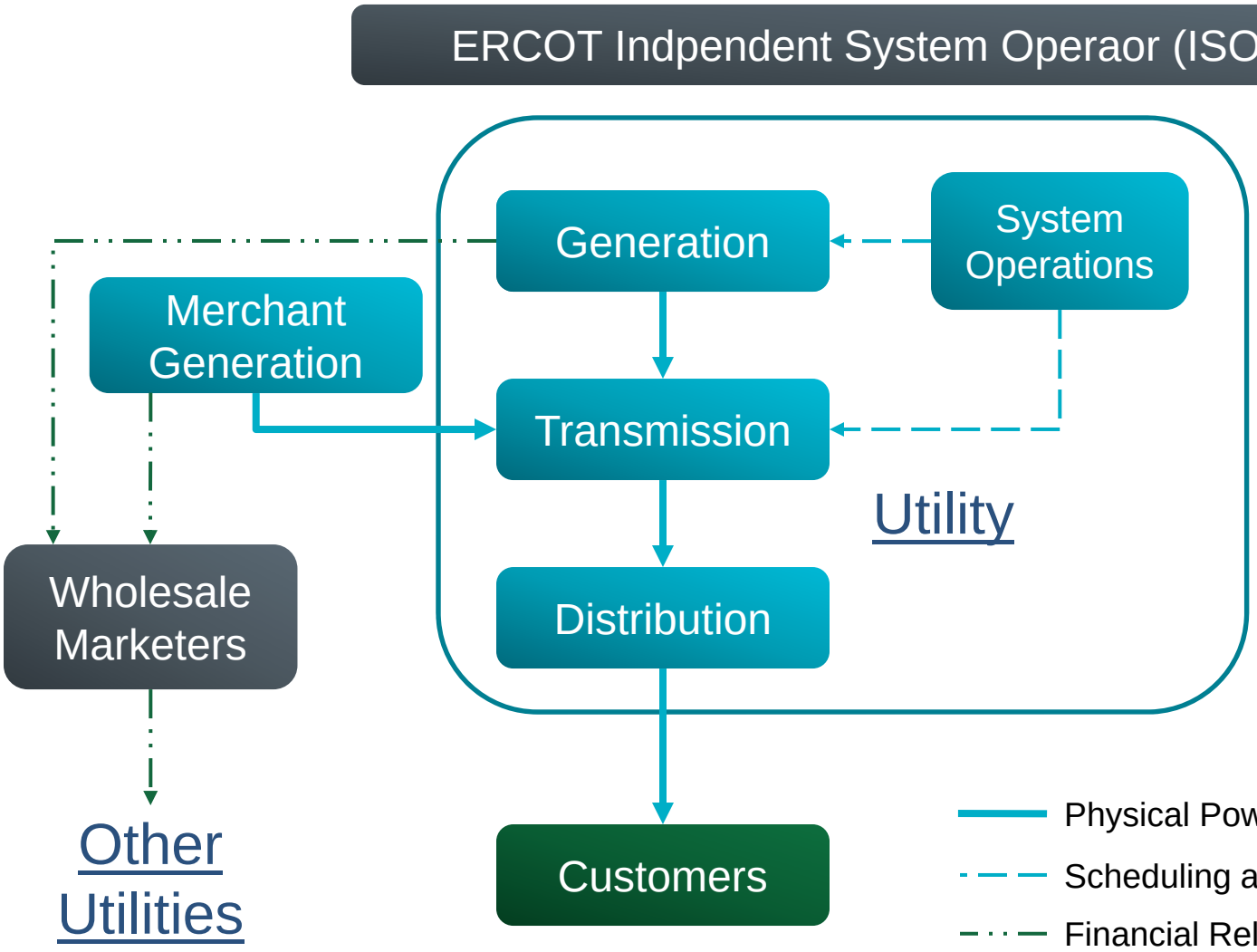
Investor-owned utilities regulated by the Public Utility Commission of Texas (PUCT), created in 1975

Municipally-owned utility rates regulated by city governments (and still are)

Electric cooperative rates regulated by co-op boards (and still are)



Wholesale market deregulation (mid-1990s)



- **Texas Legislature opened the doors to competitive wholesale producers**
- **Ensured open access to transmission system**

Reasons behind wholesale deregulation

Competitive Pressure

New companies wanted to build generation and market energy to buyers

Customers wanted to select their energy provider

General belief it would bring more efficient resources to market and lead

Grid Operations & Reliability

State regulators and many market participants supported an impartial ISO

ISO would ensure that the electric grid remained reliable and there was fair access to the transmission system

ERCOT Market v1 – Wholesale (1996-2001)

Transmission Providers:
May or may not own distribution or generation; may or may not be a control area

Generators:
Utility-owned or independent

Power Marketers:
Independent or operated by independent generators or utilities

- Bilateral Market
  - Transactions between buyer and seller
  - No Power Exchange or market clearing price
  - ISO does not know the price of transactions
- Control areas - Same as before
- ERCOT transitions from reliability coordinator to Independent System Operator

The Big Game Changer: Retail Competition

1999: Texas Legislature Passed Senate Bill 7

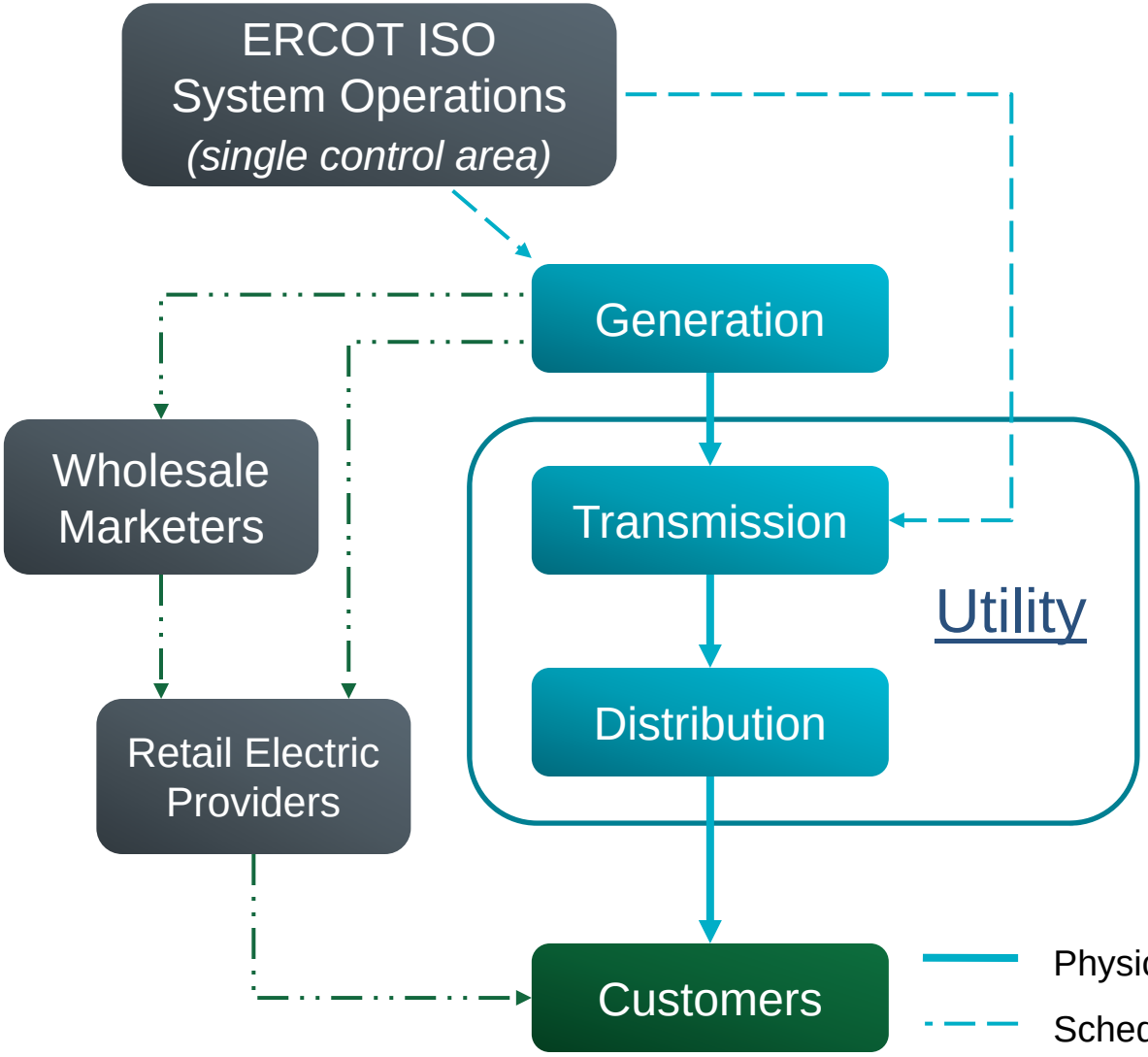
Public Utility Commission issued series of rules and orders to enable market launch

ERCOT given responsibility as the Independent Organization for the region:

- Maintain reliability
- Operate wholesale market
- Ensure equal access to the grid for new entrants
- Operate retail market

January 1, 2002: Go-live

Retail & wholesale market deregulation (2002)

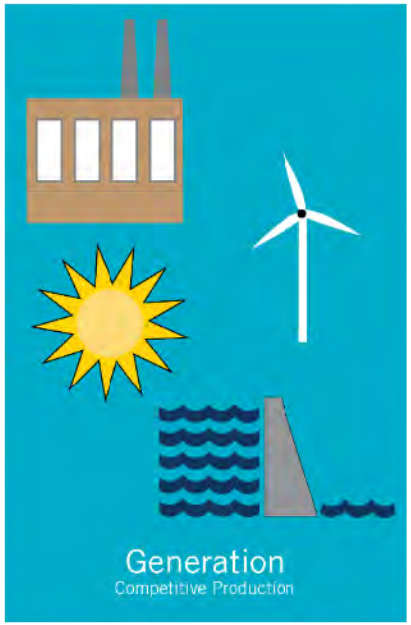


Texas Legislature in 1999 unbundled Investor-Owned Utilities

- Generation companies sell into the competitive wholesale market
- Retail Electric Providers buy wholesale power and re-sell to retail customers
- Retail customers allowed to choose among competing REPs
- T&D companies move power from generation to customer and remain regulated
- Municipally-owned utilities and co-ops exempted from retail competition

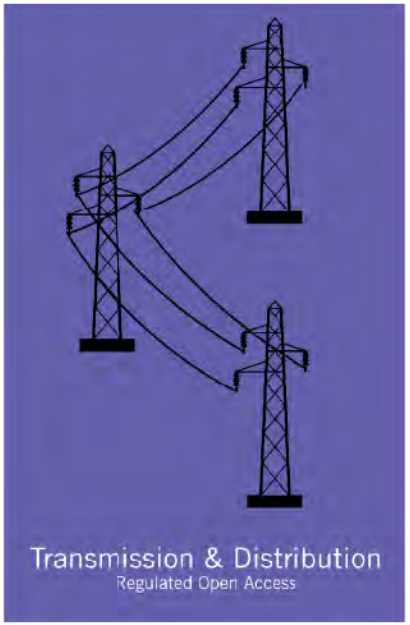
HM1

Texas Competitive Model



Generating units are owned by privately owned companies
- Except for municipal and cooperative units

Compete in ERCOT market to serve load
- Market is overseen by PUC.



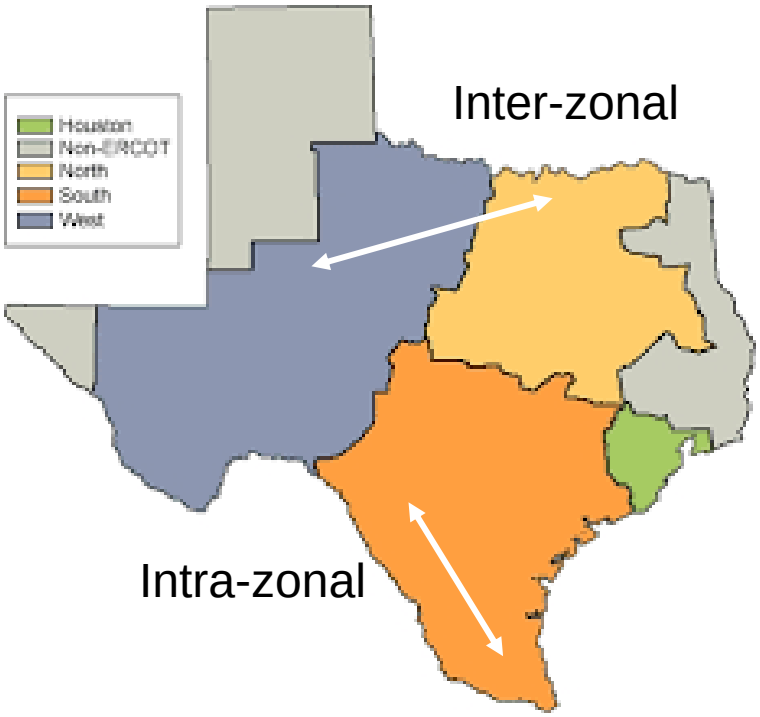
Transmission and distribution lines and related facilities are owned and operated by regulated utilities.
- Utilities are regulated by PUC.

Consumer's electric load is served by competitive retailers.
- o Except in municipal and cooperative utility areas

Slide 21

HM1 this was slide 23 but I have moved for clarity/continuity of topic
Hilliard, Marie, 9/26/2018

ERCOT Zonal Market v2 – Retail, Wholesale (2002-2010)



- Bilateral
- Zonal dispatch
- Balancing Energy Services
  - Not a true ‘spot market’
  - Directly assigned costs of inter-zonal congestion, but not intra-zonal
- Ancillary Services
- No Day-ahead Energy Market
- Portfolio-based schedules
- Transmission Congestion Rights
- Single Control Area

ERCOT Zonal Market

Zonal Portfolio Model

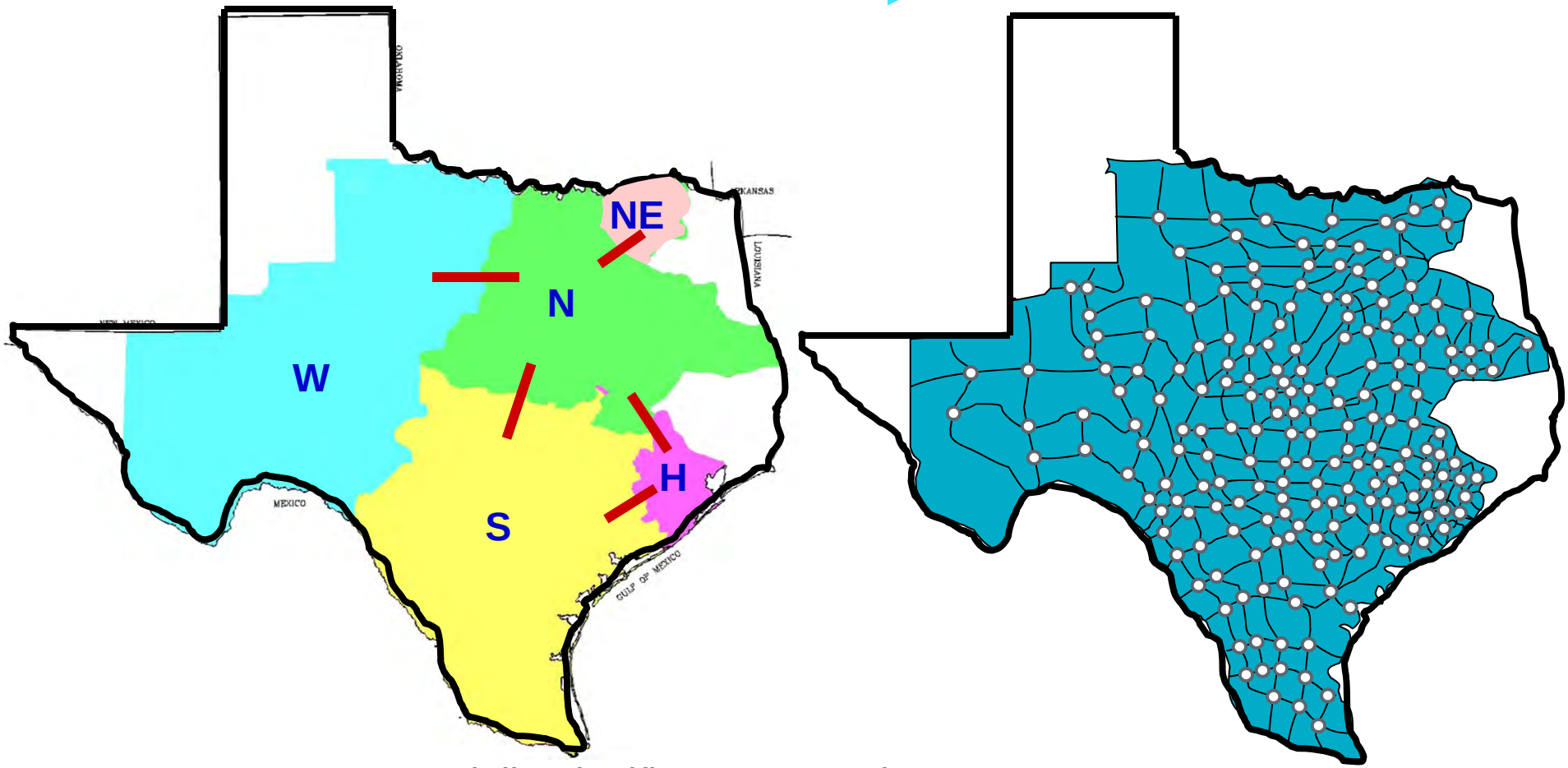
- Five wholesale pricing “nodes” (congestion zones)
- Commercially Significant Constraints (CSCs) for inter-zonal congestion management
- Average shift factors within congestion zones
- Zonal balancing energy deployed by ERCOT
- Zonal congestion costs directly assigned based upon cost causation

Local Congestion Management

- Unit specific deployments -- ‘out of merit’ commitment & dispatch
- Mitigated offers
- Local congestion costs uplifted to all load

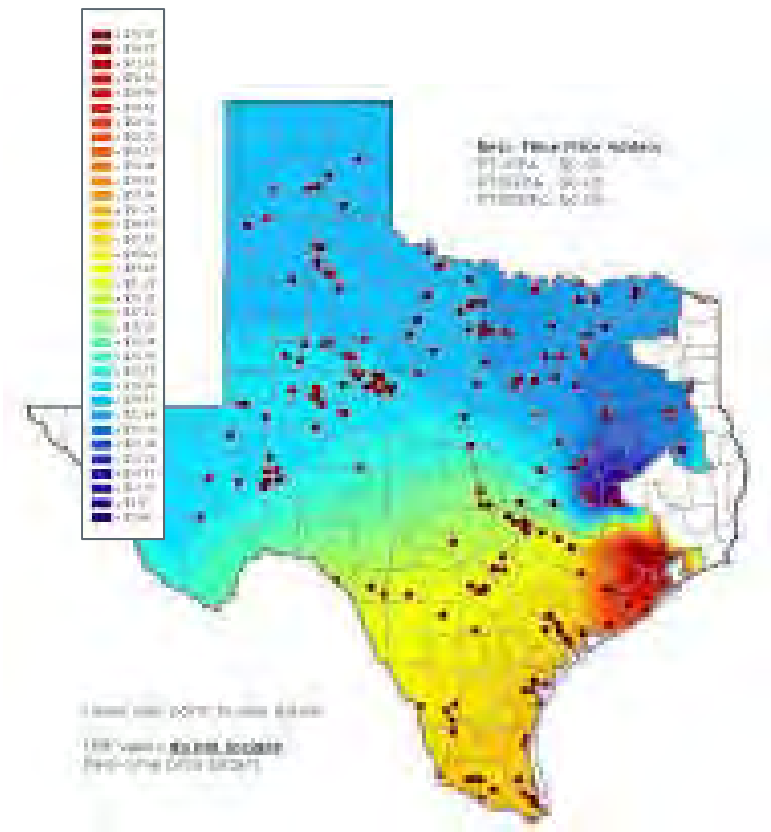
The Next Big Game Changer: Transition to Nodal

Zonal ■ ■ ■ ■ ■ ■ ■ ■ ▶ Nodal



Commercially Significant Constraint

ERCOT Nodal Market v3 (2010 to present)



5 minute Locational Marginal Prices

- >550 Resource Nodes
- >4,000 Load points

15-minute settlement

Day-Ahead Energy Market with co-optimized energy and Ancillary Services

Congestion costs directly assigned based upon cost causation

Transmission capacity auctioned off point to point

Congestion Revenue Rights to enable hedging

ERCOT Control Room (Taylor, TX)

Interconnection Dependencies

System Control

System Security

Emergency Operation

Operating Personnel

Operations Planning

Communications and Metering

System Control

Automatic Control Systems

Time correction

Generating Unit Operating Capability Verification

Interruptible Load Used as Capability verification Procedure

Interchange classifications

Application of under-frequency Relaying

Application of ancillary services

Maintaining voltage Profile

System Security

Responsive Reserves

Unit and Line Outages

Emergency Operations

Emergency assistance

Operation to Maintain Transmission System security

Adverse Weather Operation

Short Supply operations

Emergency Load shedding Plan

Black start plan

Operating Personnel

Selection and training of System Operators

Annual Training Classes

Certification of Operators

Operations Planning

Generation facilities

Transmission security criteria

System protective relaying

Communications and Metering

- Inter-control area communications guidelines
- Inter-control Area telemetry guidelines
  - Inter-Control Center Protocol (ICCP)
  - Multiple data points from all Resources every 2 seconds
- Inter-control area Metering Guidelines

Questions

joel.mickey@ercot.com

(512) 248-3925