# Course notes for EE394V Restructured Electricity Markets: Locational Marginal Pricing

Ross Baldick



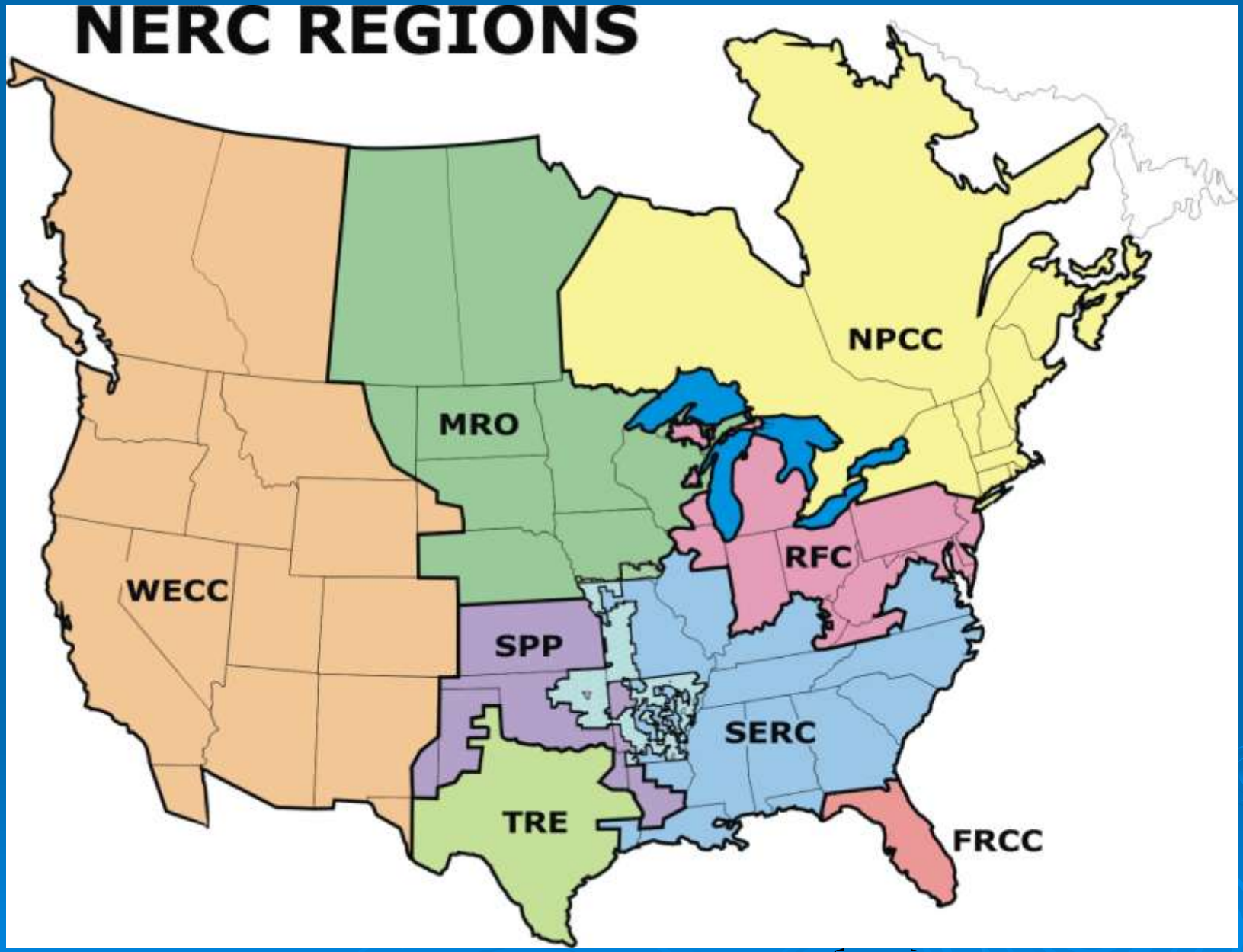
www.ece.utexas.edu/~baldick/classes/394V/EE394V.html

# 1
# Recent History of Electricity Market Restructuring in Texas

1. Regional entities,
2. Texas and the Electric Reliability Council of Texas (ERCOT),
3. Regulatory jurisdiction,
4. Milestones in Texas electricity restructuring,
5. The locational marginal pricing or “nodal” market,
6. Capacity adequacy concerns,
7. Conclusions,
8. Homework Exercise.

# 1.1 Regional Entities:
## Responsible for reliability of the bulk transmission system

- Electric Reliability Council of Texas, Inc. (ERCOT) ("Texas Regional Entity", TRE),
- Florida Reliability Coordinating Council (FRCC),
- Midwest Reliability Organization (MRO),
- Northeast Power Coordinating Council (NPCC),
- ReliabilityFirst Corporation (RFC),
- SERC Reliability Corporation (SERC),
- Southwest Power Pool, Inc. (SPP),
- Western Electricity Coordinating Council (WECC).




Source: North American Electric Reliability Corporation. Available from: www.nerc.com/fileUploads/File/AboutNERC/maps/NERC_Regions_Color_072512.jpg.

# 1.2 The Electric Reliability Council of Texas (ERCOT)

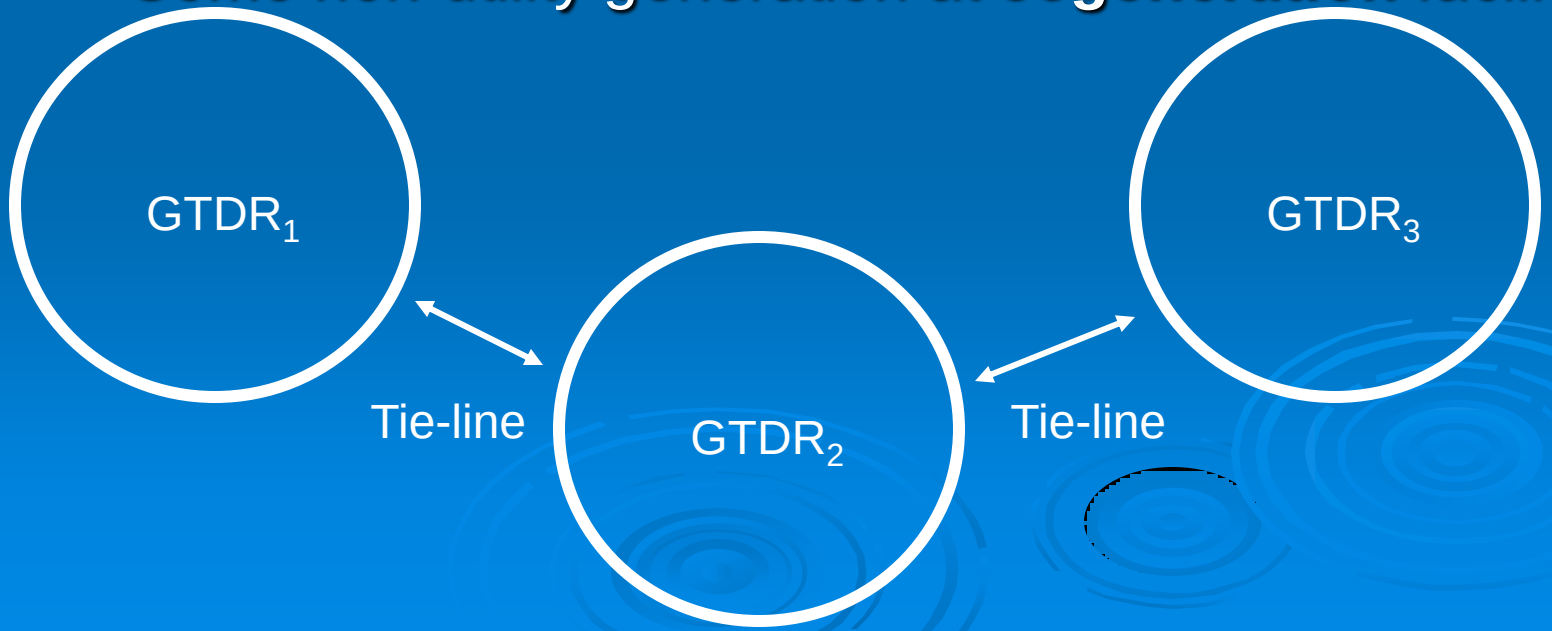
- One of eight regional entities (formerly "reliability councils") in North America:
  - responsible for maintaining "reliability" in ERCOT region,
  - regional entities under authority of "North American Electric Reliability Corporation" (NERC) for purposes of "reliability."
- ERCOT formed in 1970.
- Covers most of Texas:
  - approximately 6400 buses and 7800 lines,
  - will not discuss the rest of Texas in detail.

# 1.3 Regulatory jurisdiction

- Most electricity entities in ERCOT are under "economic" regulatory jurisdiction of the Public Utility Commission of Texas (PUCT).
- In other states, and in the non-ERCOT part of Texas, economic regulation is typically through both:
  - The Federal Energy Regulatory Commission (wholesale trade), and
  - The relevant state Public Utility Commission (retail).
- Split of jurisdiction complicates restructuring.

# 1.4 Milestones in Texas electricity restructuring 1995-2010

- Prior to 1996, most electricity supplied by vertically integrated utilities:
  - Generation (G), transmission (T), distribution (D), and retail (R) function combined in one company,
  - Some wholesale trade on “tie-lines” between them,
  - Some non-utility generation at **cogeneration** facilities.



# Milestones in Texas electricity restructuring 1995-2010

- Vertical integration and variations typical in North America (and worldwide) prior to restructuring:
  - In principle, vertical integration is the most effective arrangement if industry is “natural monopoly:”
    - Economies of scale of construction or operation large enough that one company in a region can construct and operate the system more cheaply than two or more.
- Some variations such as:
  - Generation (G) and transmission (T) in one company,
  - Distribution (D) and retail (R) in another.

# Milestones in Texas electricity restructuring 1995-2010

- Retailer had exclusive franchise to sell to retail customers in franchise area:
  - Retail tariffs set by regulator to recover **cost-of-service** to utility plus regulator-approved return on equity,
  - Limited incentive to utility to minimize costs or innovate,
  - “Averch-Johnson” bias to over-invest in capital compared to optimal.

# Milestones in Texas electricity restructuring 1995-2010

- By 1990s, change in perception about regulated monopolies due to:
  - Successful restructuring of other industries,
  - high costs of nuclear generation,
  - new, smaller combined-cycle generators.
- Realization that G, T, D, R could be separated:
  - Generation sector not necessarily natural monopoly, so potential for competition,
  - Transmission and distribution still understood to be natural monopoly, and could remain regulated.

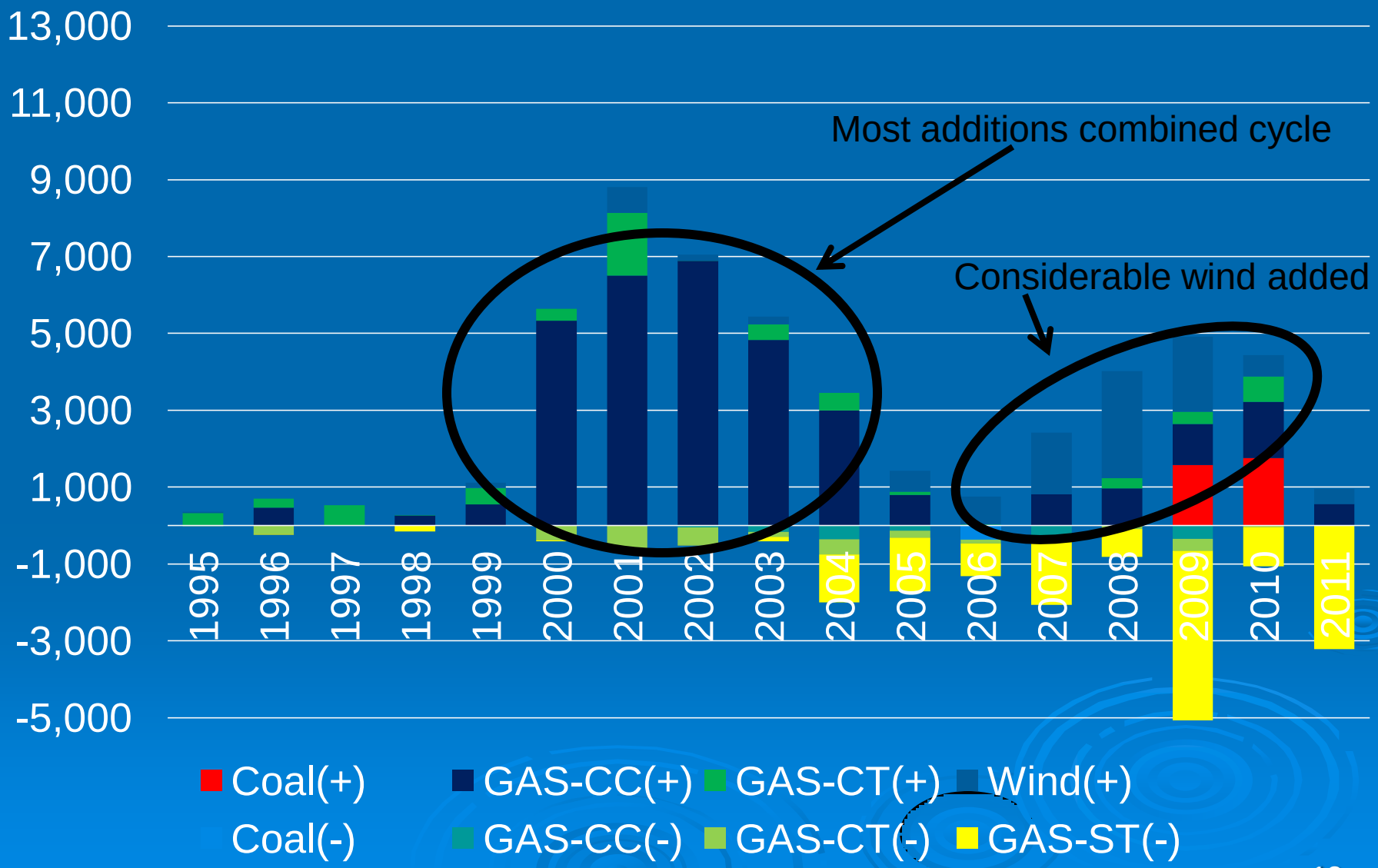
# Milestones in Texas electricity restructuring 1995-2010

- 1995, amended Public Utility Regulatory Act provided for wholesale competition involving non-utilities, principally **Independent Power Producers** (IPPs)—independently owned generators,
- Consistent with world-wide trend to harness competition in generation sector.
- 1996, ERCOT **Independent System Operator** (ISO) formed and wholesale competition involving non-utilities began:
  - Most new entry was combined-cycle gas turbines.

# Milestones in Texas electricity restructuring 1995-2010

- 1999, Senate Bill 7 enabled retail competition:
  - Integrated investor-owned utilities required to "functionally unbundle" into:
    - generation, sells energy at wholesale,
    - transmission and distribution, cost-of-service regulated by Public Utility Commission,
    - Retailer, sells to consumer of energy.
  - Generation resources competing in wholesale market:
    - Many new power stations built over subsequent years, including combined cycle gas turbines and then wind.
  - New retailers competing in retail market to serve customer load.
  - Transmission and distribution remain as regulated entities receiving cost-of-service and return on equity.

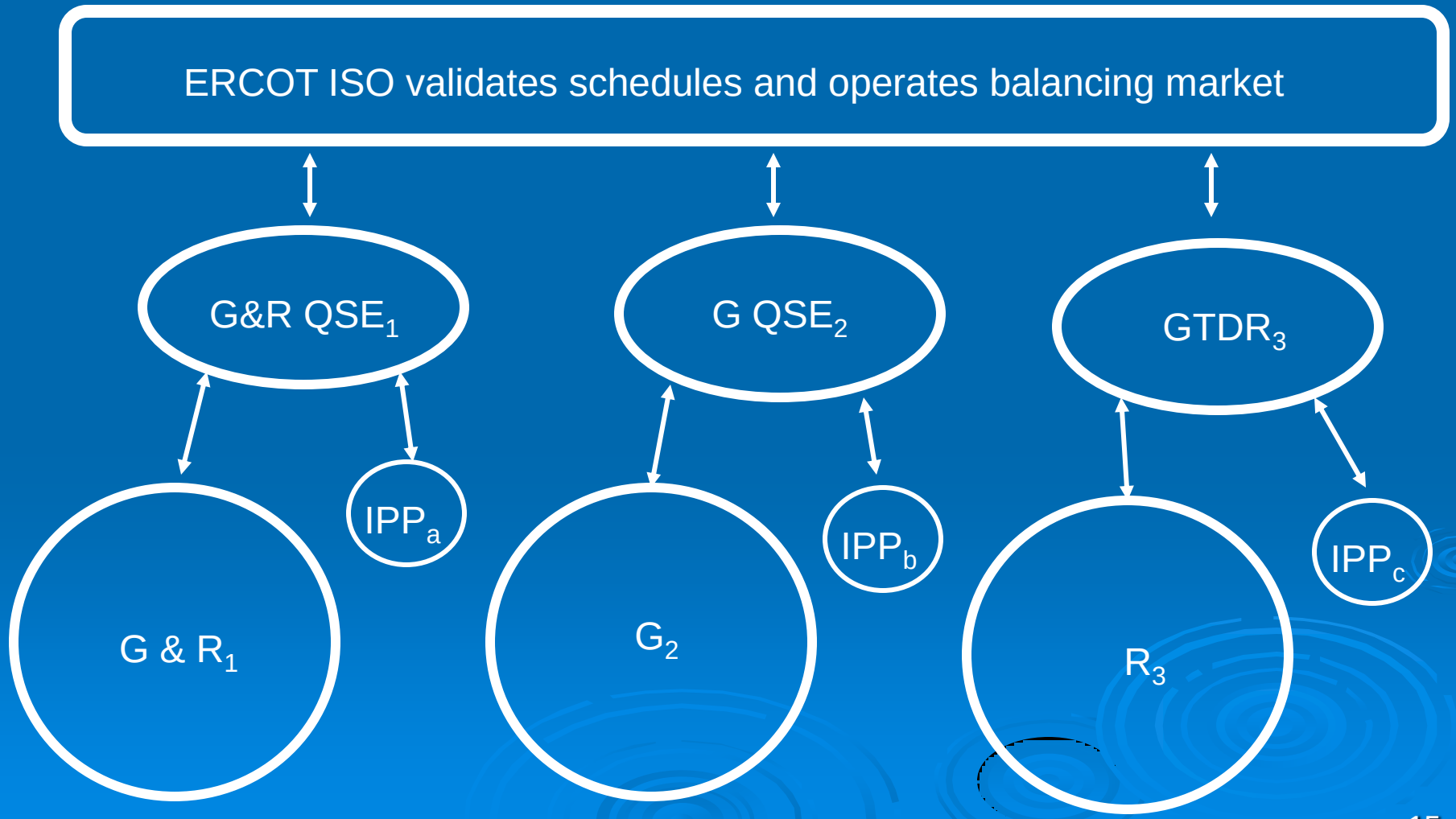
# ERCOT Capacity Expansion (+) and Retirement (-) by Fuel Type [MW]



# Milestones in Texas electricity restructuring 1995-2010

- 2001, ERCOT ISO became the single **control area operator** (**balancing authority**):
  - Day-ahead scheduling process established,
  - Qualified Scheduling Entities (QSEs) representing generators and/or retailer submitted balanced specification of generation to meet specified demand, the **schedule**,
  - **Balancing market** established to cope with deviations of actual from scheduled generation and demand.

# Milestones in Texas electricity restructuring 1995-2010



# Milestones in Texas electricity restructuring 1995-2010

- Transmission issues:
  - If result of schedule would overload the transmission system, then **re-dispatch** of generation necessary compared to schedule,
  - Individual generators re-dispatched and QSEs compensated,
  - All costs of re-dispatch to relieve transmission constraints due to initial schedule were **uplifted** (charged) to retail customers,
  - Predictable result was that QSEs submitted schedules that would have overloaded transmission constraints and were then compensated for relieving the overloads that their schedules would have caused.

# Milestones in Texas electricity restructuring 1995-2010

- 2002, retail market began.
- 2002, effects of inter-zonal transmission constraints represented in zonal wholesale prices so that only re-dispatch costs due to “local” transmission constraints were then uplifted.
- 2002-2005, hundreds of millions of dollars of local re-dispatch costs uplifted.
- 2005, decision to change to a nodal wholesale market.
- Nodal market opened December 2010.

# 1.5 The nodal market from December 2010

- Centrally dispatched real-time market, similar role to the previous balancing market, but with nodal representation of transmission.
- Centrally dispatched day-ahead market:
  - Each generator can offer its capacity to be used to generate energy, or provide for ancillary services, or a mixture of energy and ancillary services (or can schedule),
  - Energy and related ancillary services acquired in a single day-ahead auction run by ERCOT,
  - Determines short-term forward prices.

# The nodal market from December 2010

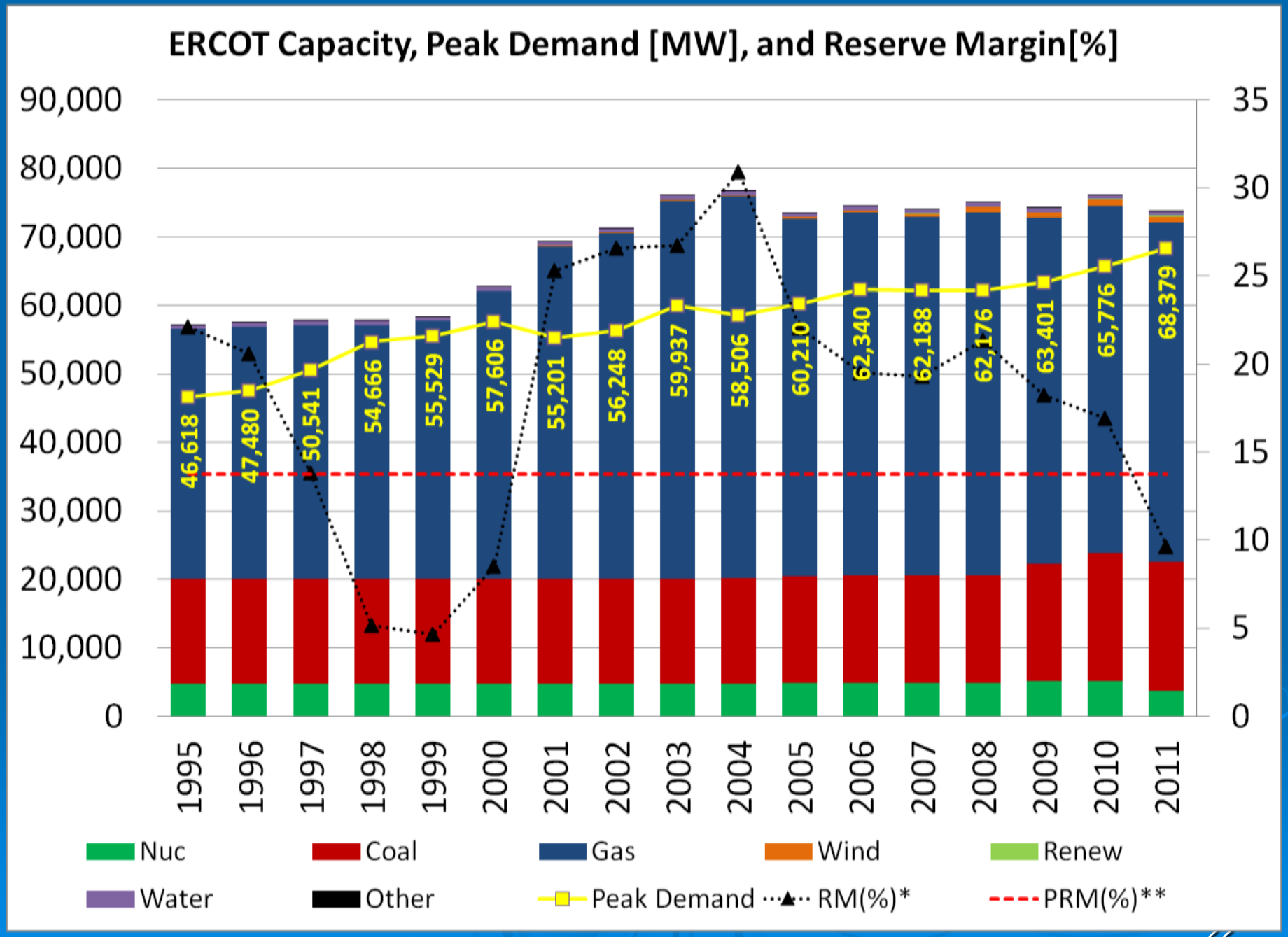
- Uplift of only a much smaller fraction of overall market value compared to previous zonal market, including costs of:
  - Ancillary services,
  - Cost of losses,
  - Re-dispatch costs due to transmission constraints not represented in nodal market,
  - Reliability unit commitment.
- Generators exposed to locational prices, but consumption exposed to zonal averages.

# The nodal market from December 2010

- Locational pricing map for real-time prices available from: http://www.ercot.com/content/cdr/contours/rtmLmpHg.html
- Do you have retail choice for your retail electricity purchases?

# 1.6 Capacity adequacy concerns.

- After 2003, most new generation additions have been wind:
  - West Texas wind mostly generates off-peak,
  - Wind capacity does not contribute much to meeting peak demand:
    - "ERCOT Capacity" on next slide shows estimate of contribution of wind to meeting demand at peak.
- Extreme temperatures in 2011 resulted in record peak demand.
- Current concerns as to whether generation capacity will be adequate in future.


ERCOT Capacity, Peak Demand [MW], and Reserve Margin[%]
90,000
80,000
70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
35
30
25
20
15
10
5
0
46,618
47,480
50,541
54,666
55,529
57,606
55,201
56,248
59,937
58,506
60,210
62,340
62,188
62,176
63,401
65,776
68,379
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
Nuc
Coal
Gas
Wind
Renew
Water
Other
Peak Demand
RM(%)*
PRM(%)**

# 1.7 Conclusions

- Regional entities,
- Texas and the Electric Reliability Council of Texas (ERCOT),
- Regulatory jurisdiction,
- Milestones in Texas electricity restructuring,
- The locational marginal pricing or nodal market,
- Capacity adequacy concerns.

# References

- This is an updated version of parts of "Lessons Learned: The Texas Experience," Ross Baldick and Hui Niu, presented at the Bush School Conference on *Electricity Deregulation: Where to from here?* April 4, 2003, and appearing as Chapter 4 of Griffin and Puller, Editors, *Electricity Deregulation: Choices and Challenges*, The University of Chicago Press, 2005.

# References


- Harvey Averch and Leland L. Johnson, “Behavior of the Firm Under Regulatory Constraint,” *The American Economic Review*, 52(5):1052—1069, December 1962.

# Homework Exercise

1.1

i. Print out and turn in a copy of the ERCOT locational pricing map from: http://www.ercot.com/content/cdr/contours/rtmLmpHg.html for any time interval of your choice.

ii. Specify the highest price in ERCOT, the lowest price in ERCOT, and the difference between the highest and lowest price.