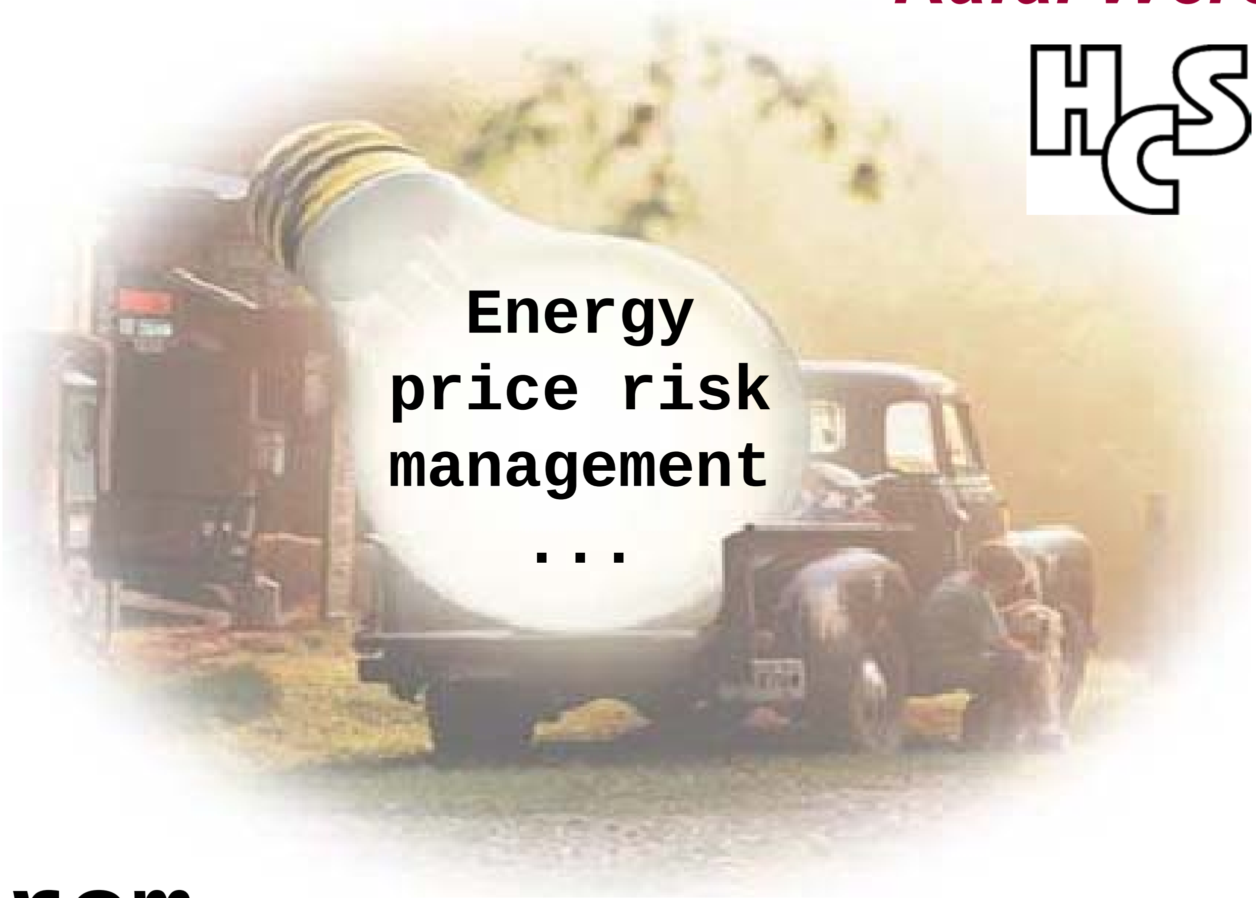
18th Max Born Symposium

Rafał Weron

Energy price risk management

...



... from
a three year
perspective

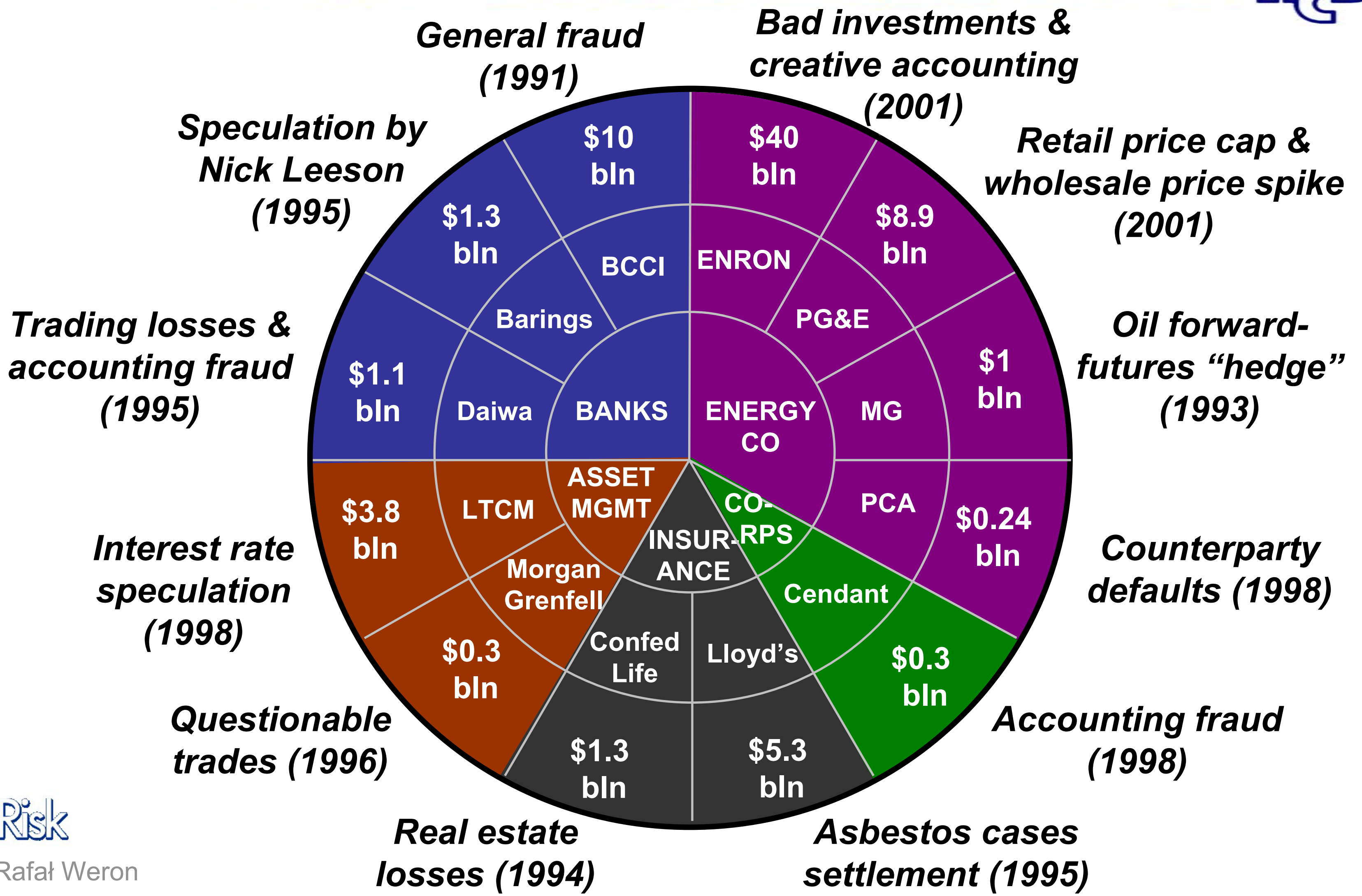
Contents

- Risk
- Deregulation
- Markets
- Blackouts
- Weather
- Spikes
- Conclusions

RISK

The possibility of incurring loss (or gain)

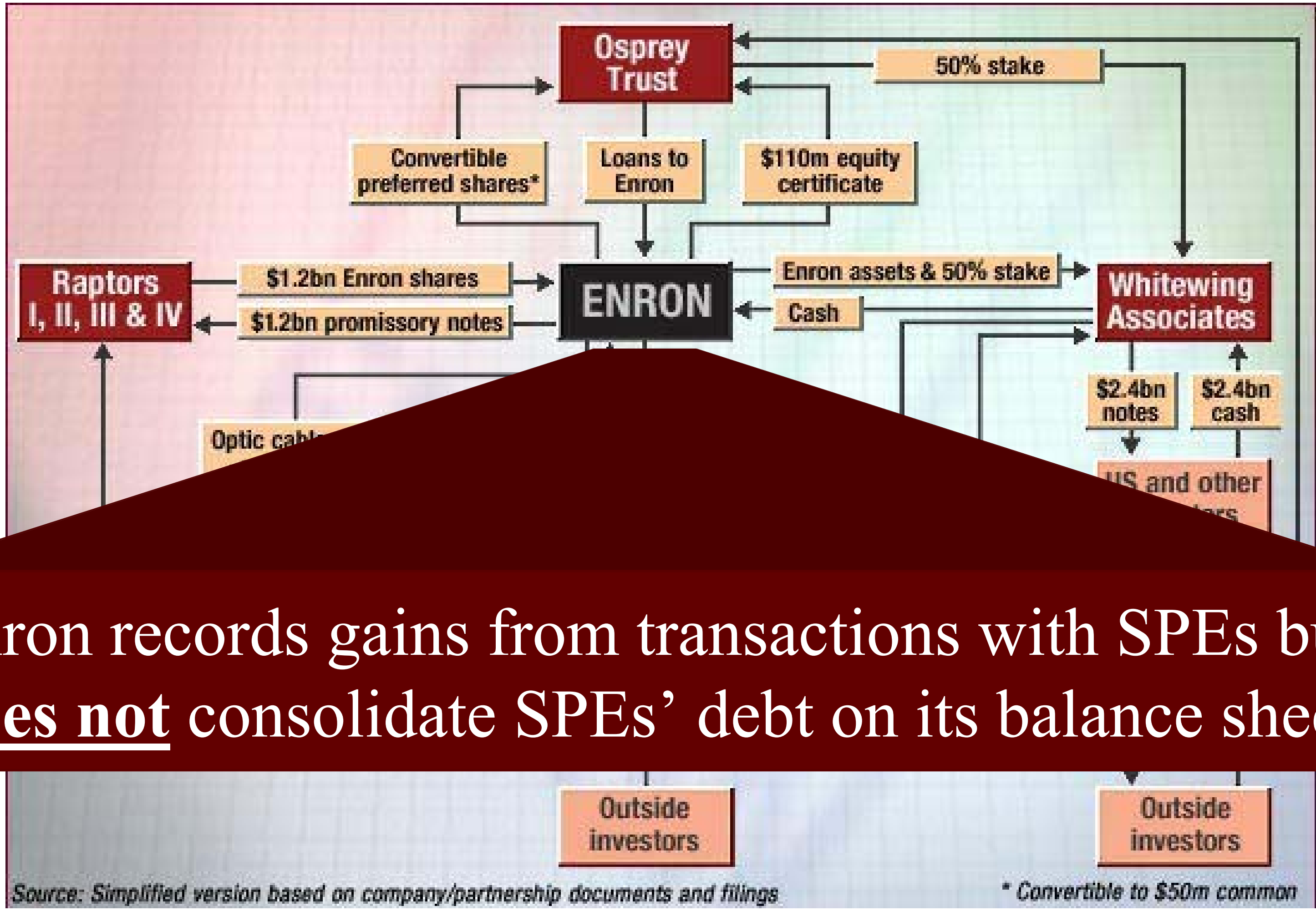
Wheel of misfortune



Enron: Problematic practices

- Accounting: “Financial engineering” with SPEs
  - hedging transactions
  - creative accounting
- Leveraging
  - financing operations
- Bad investments
  - eg. power plant in Dabhol, India
- Enron’s “culture”
  - profits, more profits, even more profits

Enron: Special Purpose Entities (SPEs)



Enron records gains from transactions with SPEs but **<u>does not</u>** consolidate SPEs' debt on its balance sheet

DEREGULATION

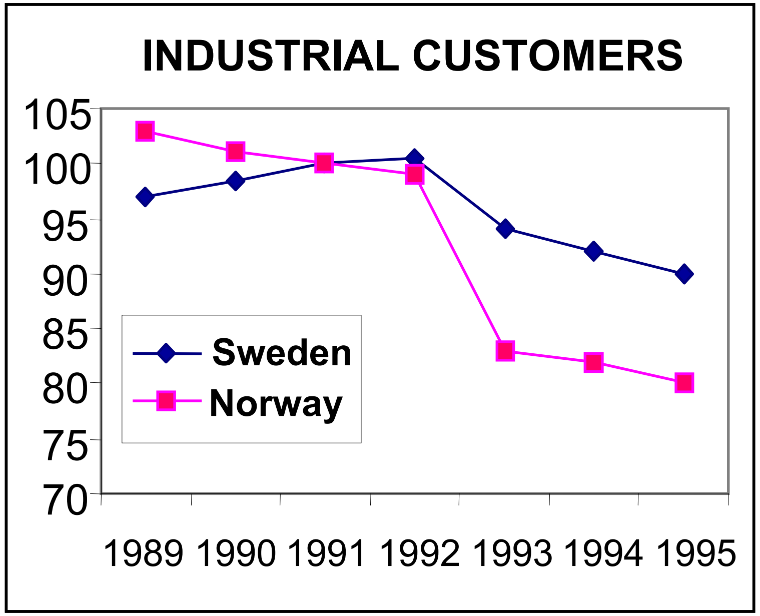
- Europe
  - England & Wales, Scandinavia, Spain, The Netherlands, Germany, Poland, Austria, …
- The Americas
  - USA: CA, PA, NJ, CT, TX, …
  - Chile, Argentina, …
- Asia/Pacific basin
  - Australia & New Zealand, …
  - Japan, …

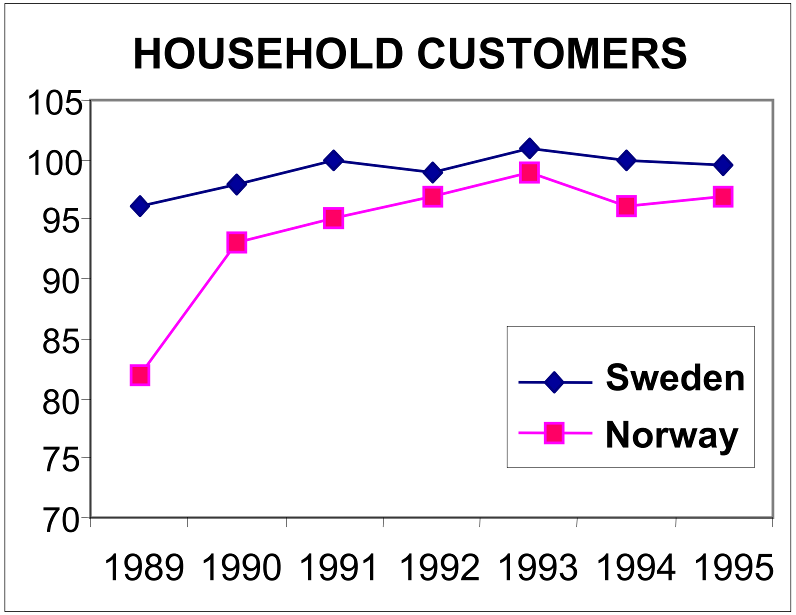
Liberalization

- Privatization
- Acquisitions by foreign companies
  - Polish EC Kraków bought by French EdF
  - German HEW, Bewag & VEAG bought by Swedish Vattenfall
- Mergers
  - PreussenElektra + Bayernwerke → E.On
  - RWE + VEW → RWE
- New Actors
  - Marketers (qualified energy brokers)
- Increase in efficiency and standards of service
- Constant battle for the CUSTOMER

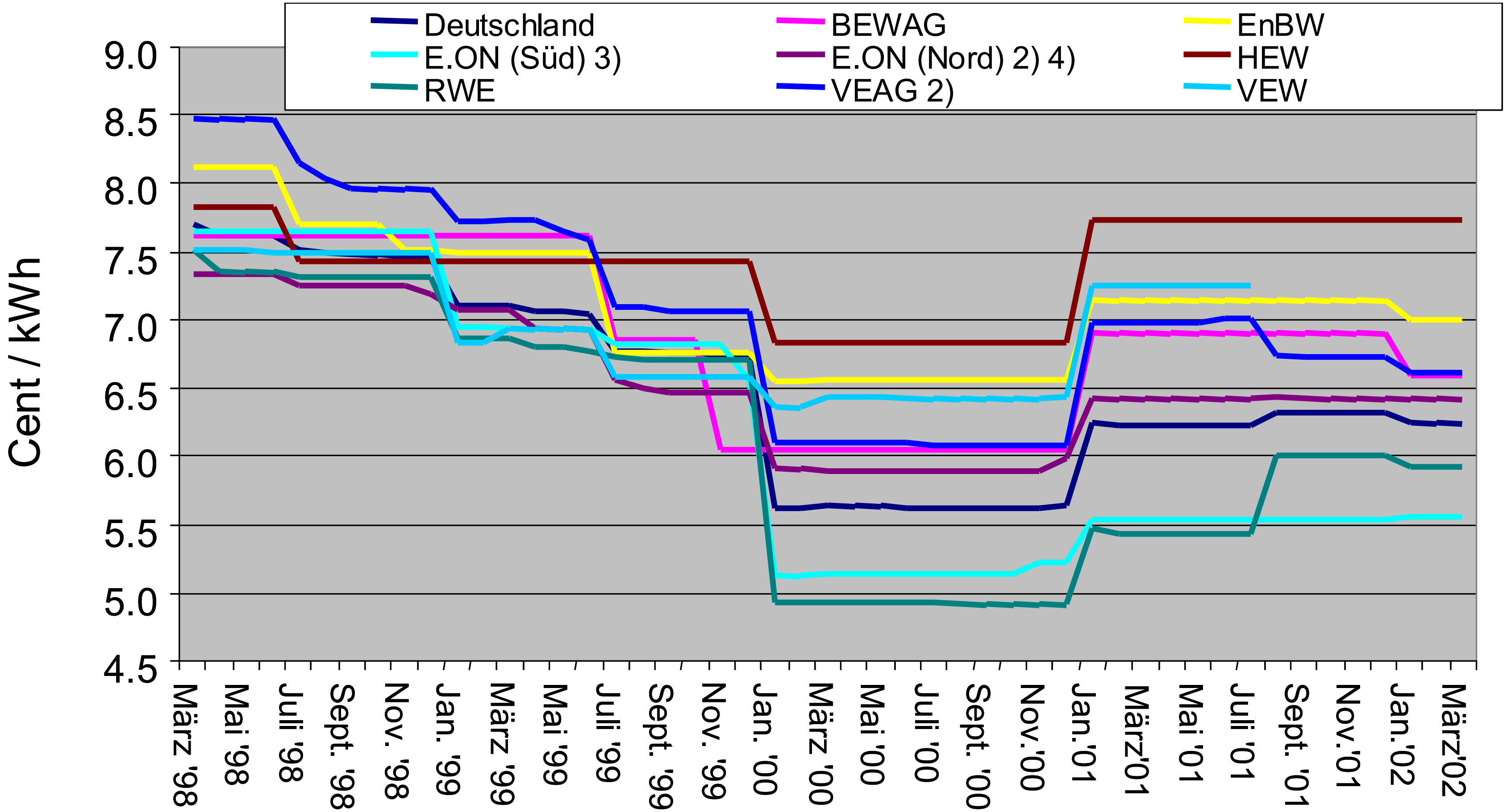
What do the customers have of it?

- Higher quality of services
- Choice of supplier
- Lower prices (?)





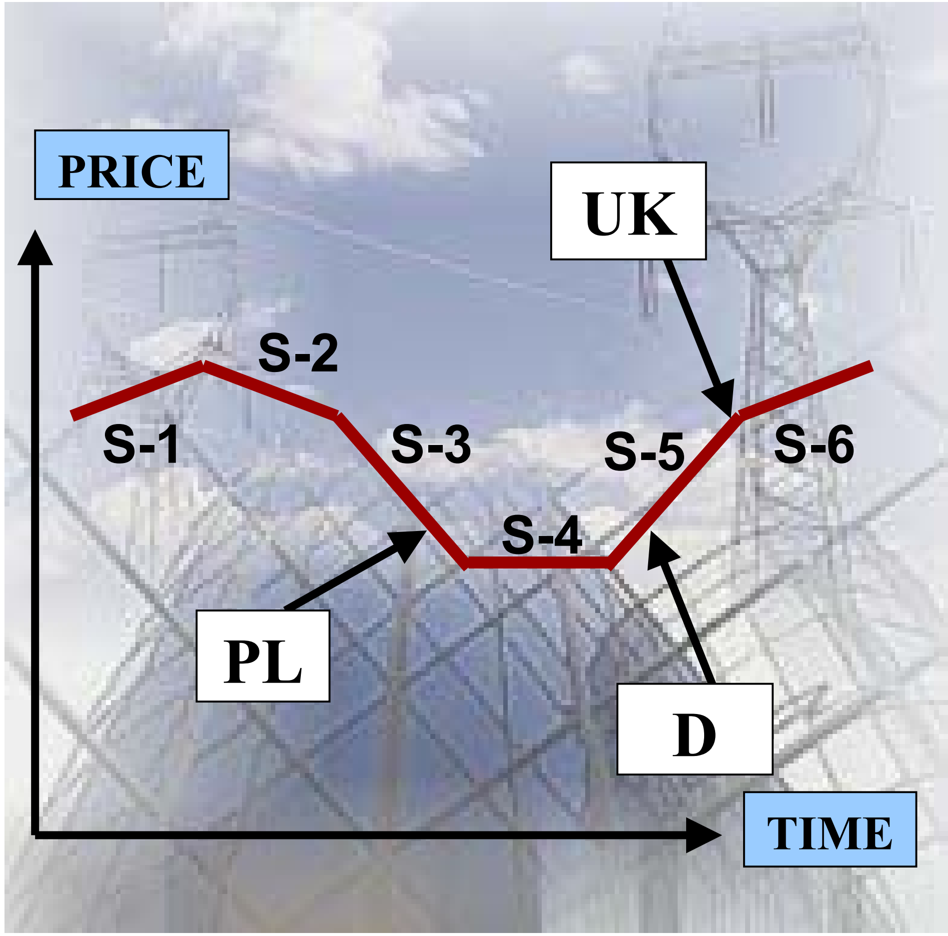
Average electricity prices for industrial customers in Germany



Prices without VAT and elecztricity tax. From January 2001, prices included KWG and EEG fees.

2) Delivery only to distributors. 3) Former area of Bayernwerk AG 4) Former area of PreussenElektra AG 5) Merged with RWE

Stages of liberalization



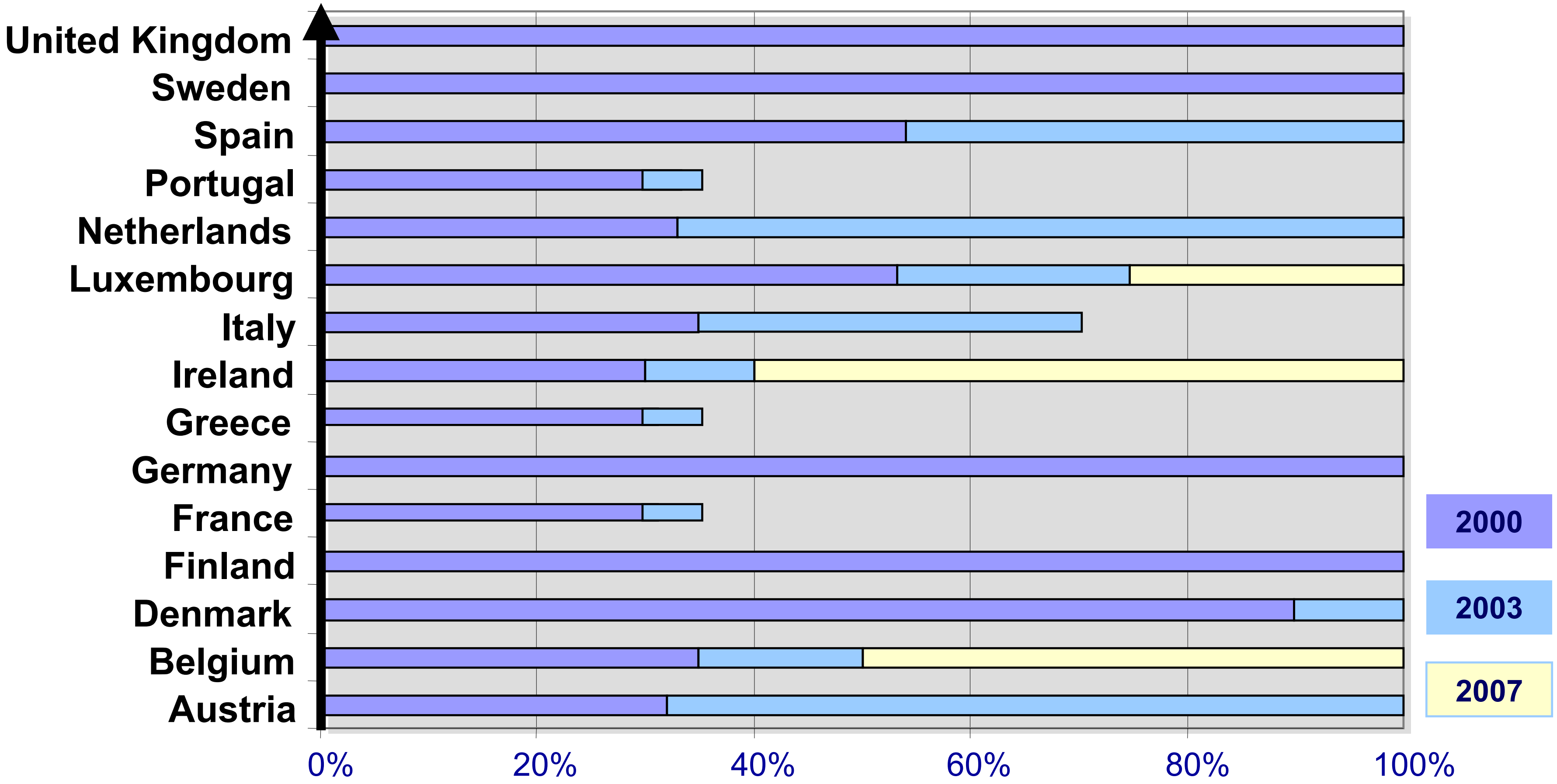
- **S-1**: State monopolies
- **S-2**: Declaration of competition
- **S-3**: Deregulation
- **S-4**: Tranquility
- **S-5**: Mergers and effects of market power
- **S-6**: Private monopolies

Opening of the EU market

- **Directive 96/92/EC** of the European Parliament
  - common rules for the production, transmission and distribution of electricity

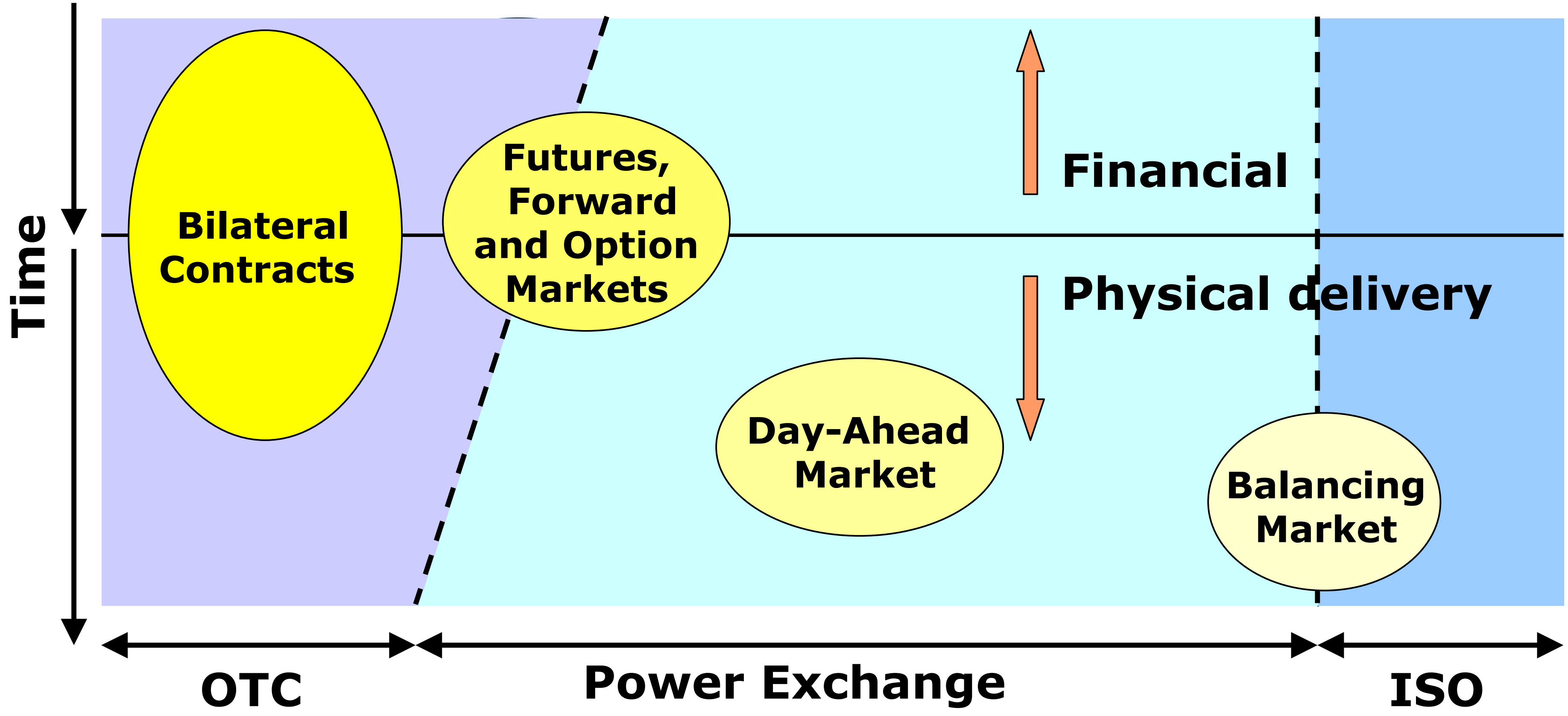
A new timetable for market opening (2001)	
2003	All EU companies free to choose electricity supplier
2004	All EU companies free to choose gas supplier
2005	All EU consumers free to choose electricity and gas suppliers

Electricity market opening - current plans

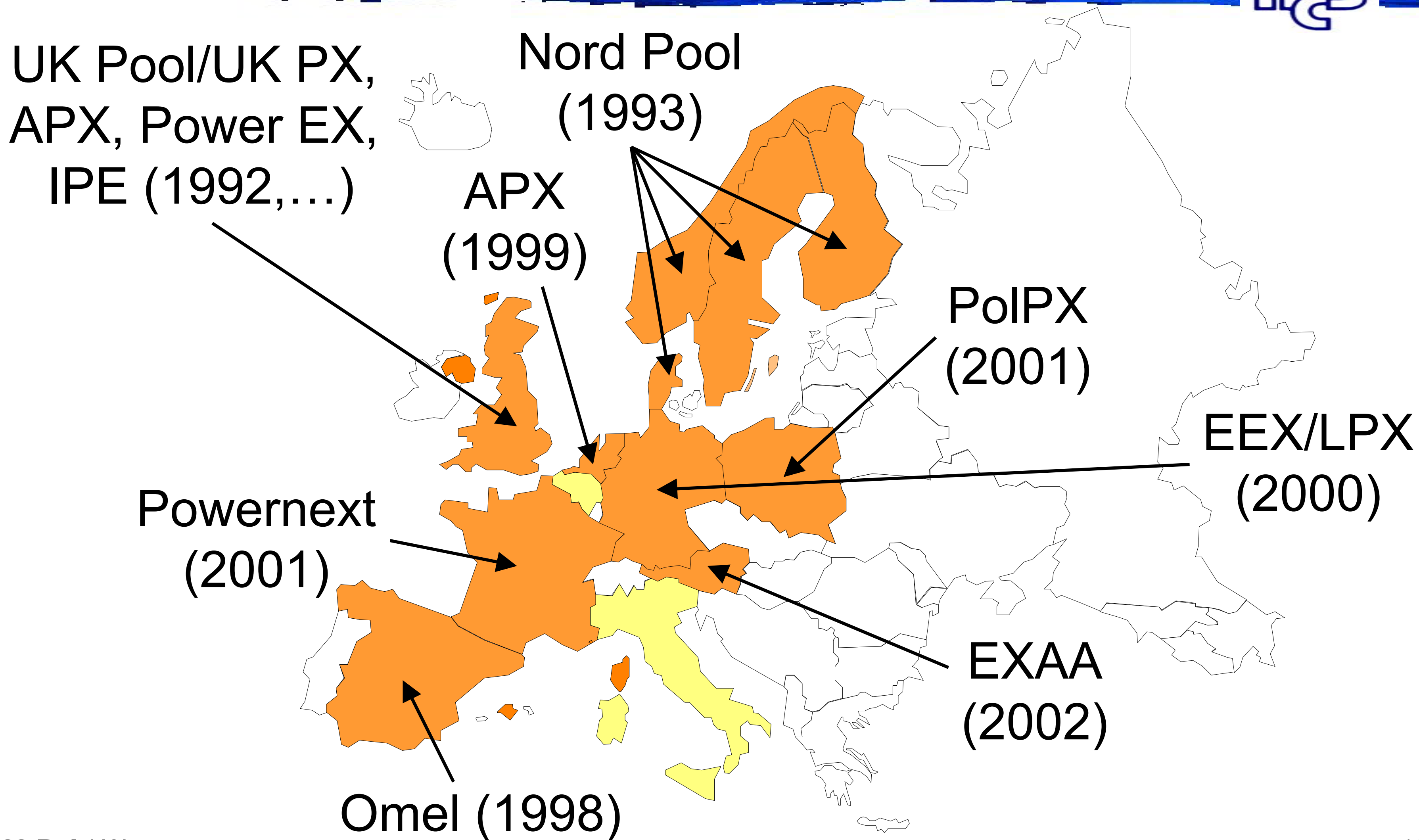


MARKETS

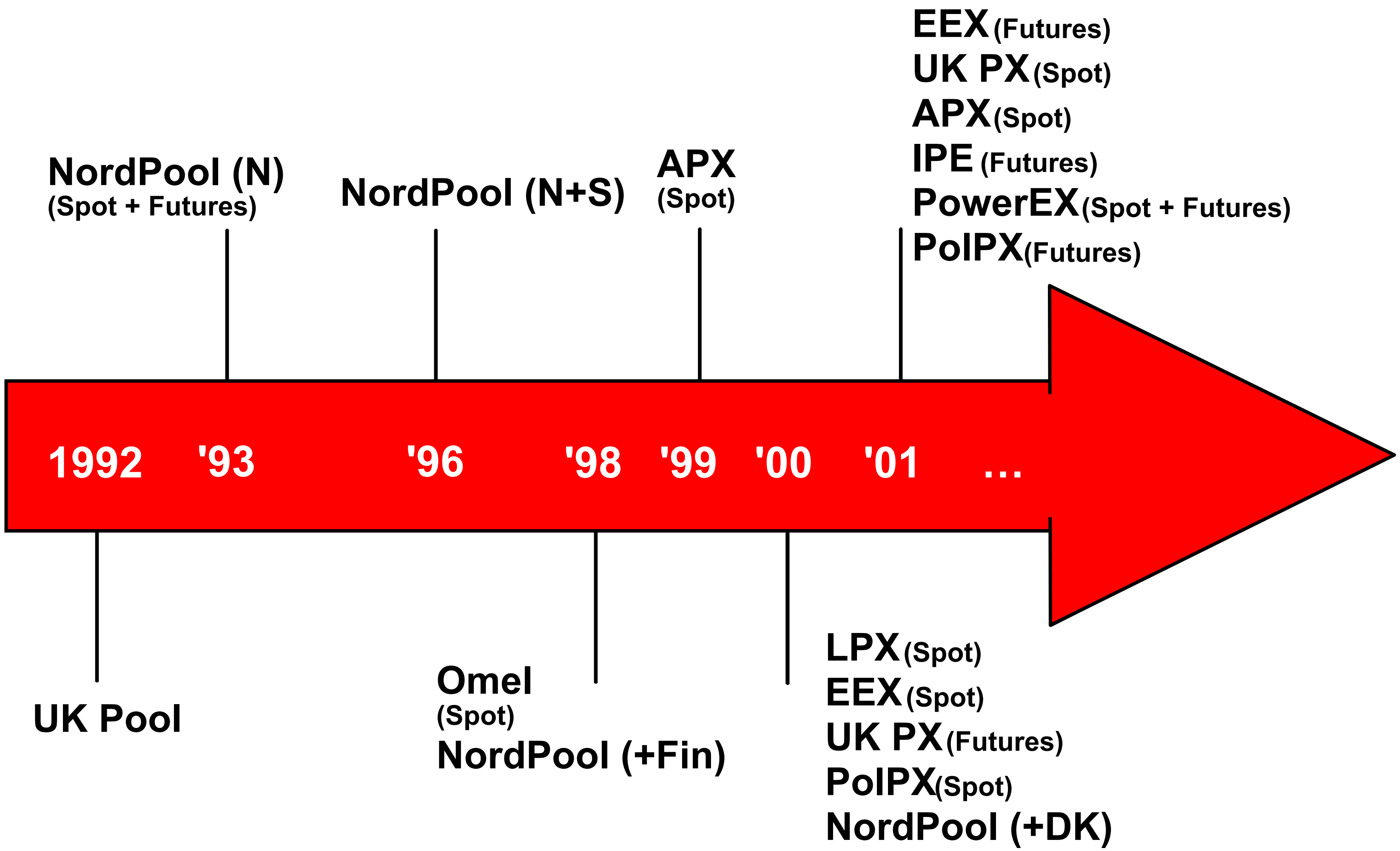
Wholesale market structure



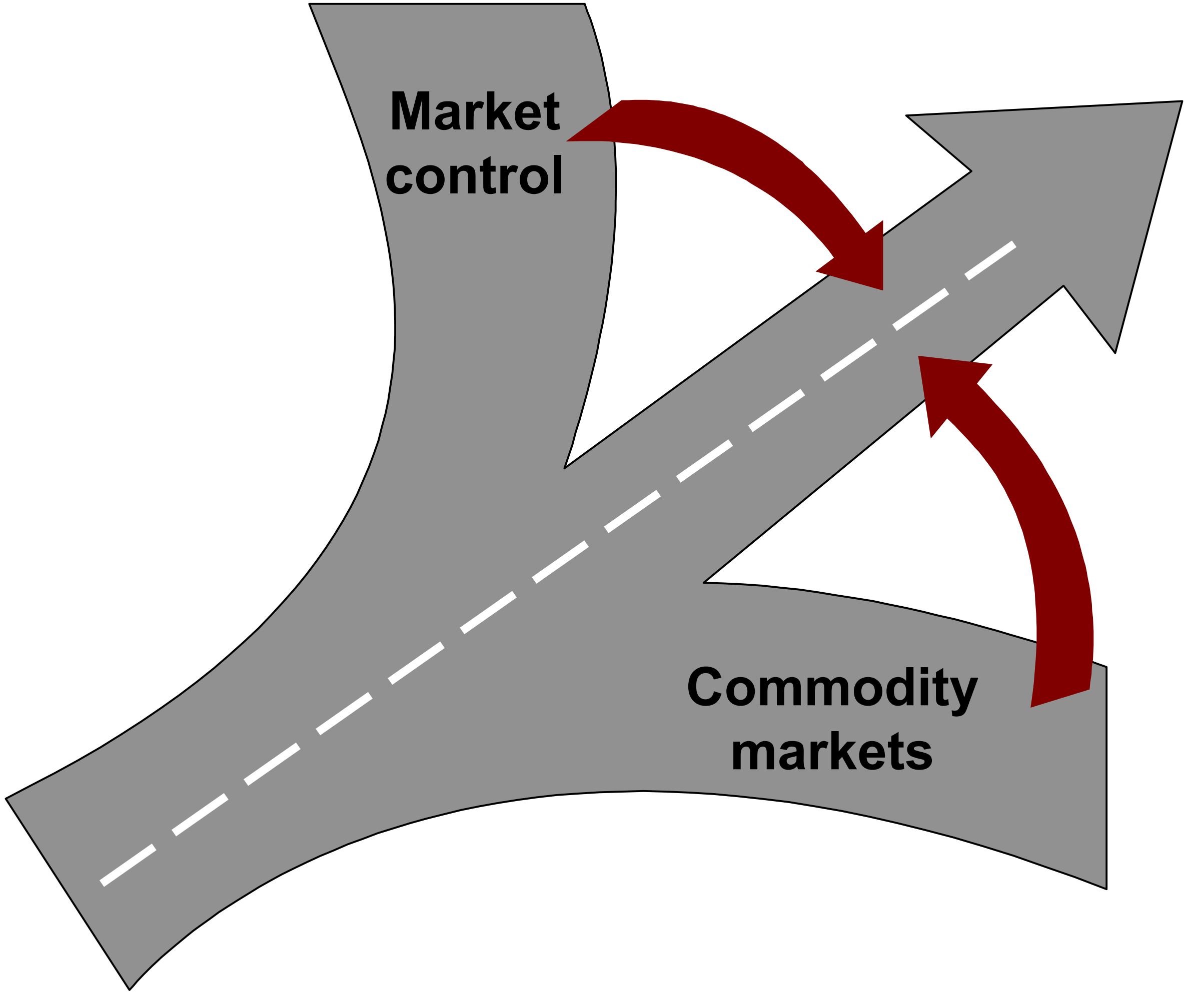
European power exchanges



European power exchanges - timeline



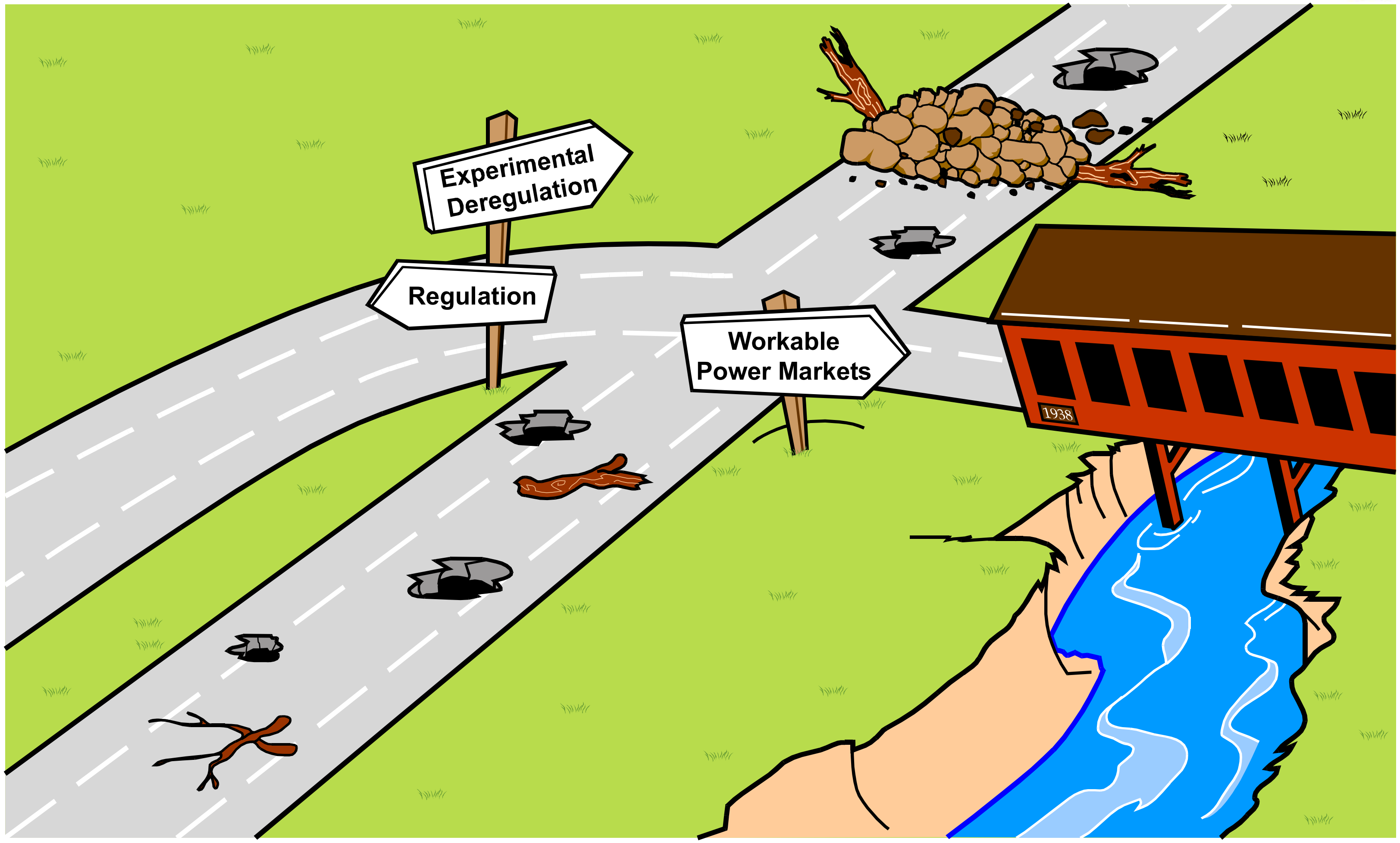
Europe: Concocting a third way



Controlled market with competitive "ornaments"

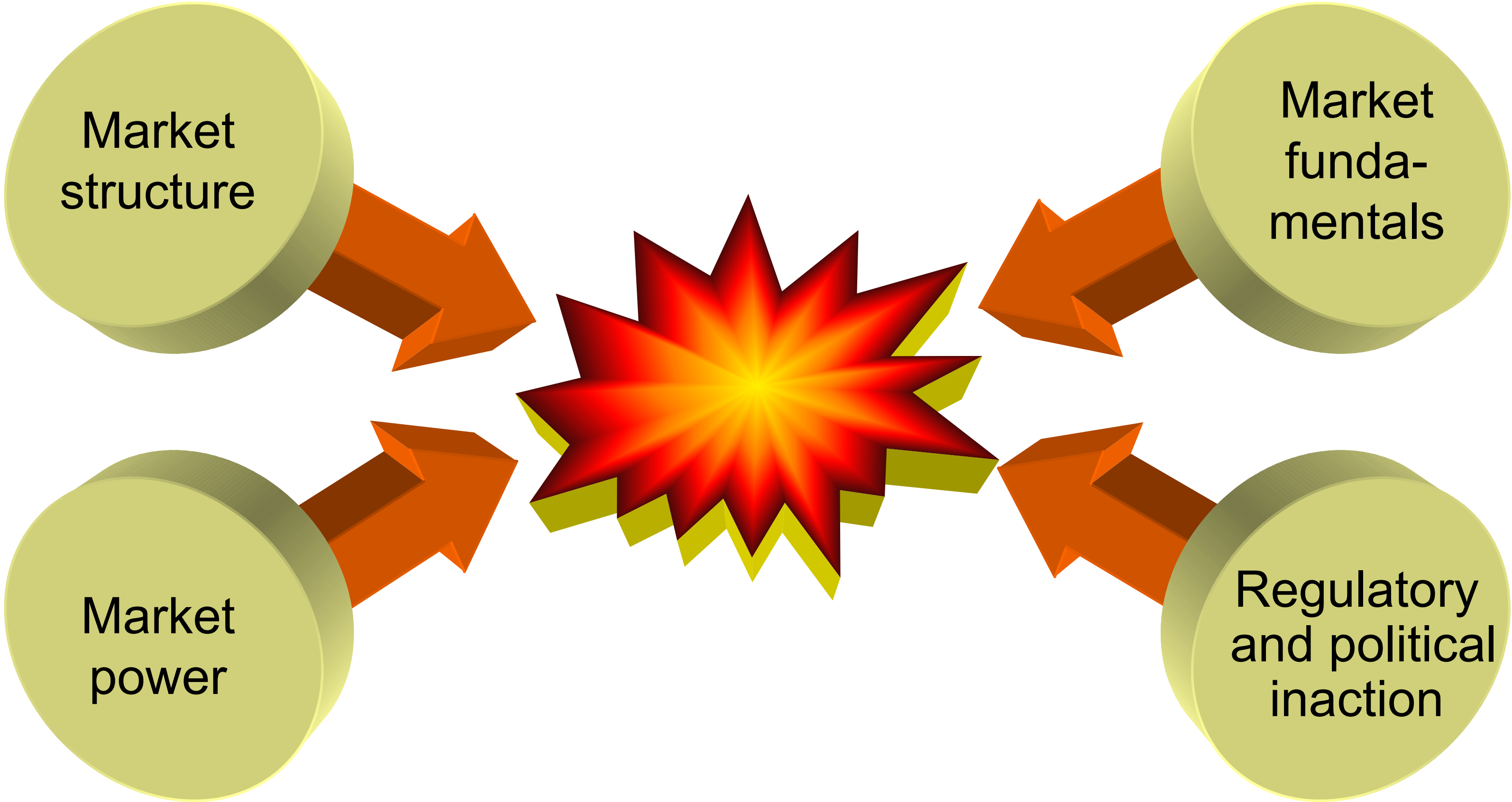
Source: Cambridge Energy Research Associates

US: Energy restructuring at a crossroads



Source: Cambridge Energy Research Associates

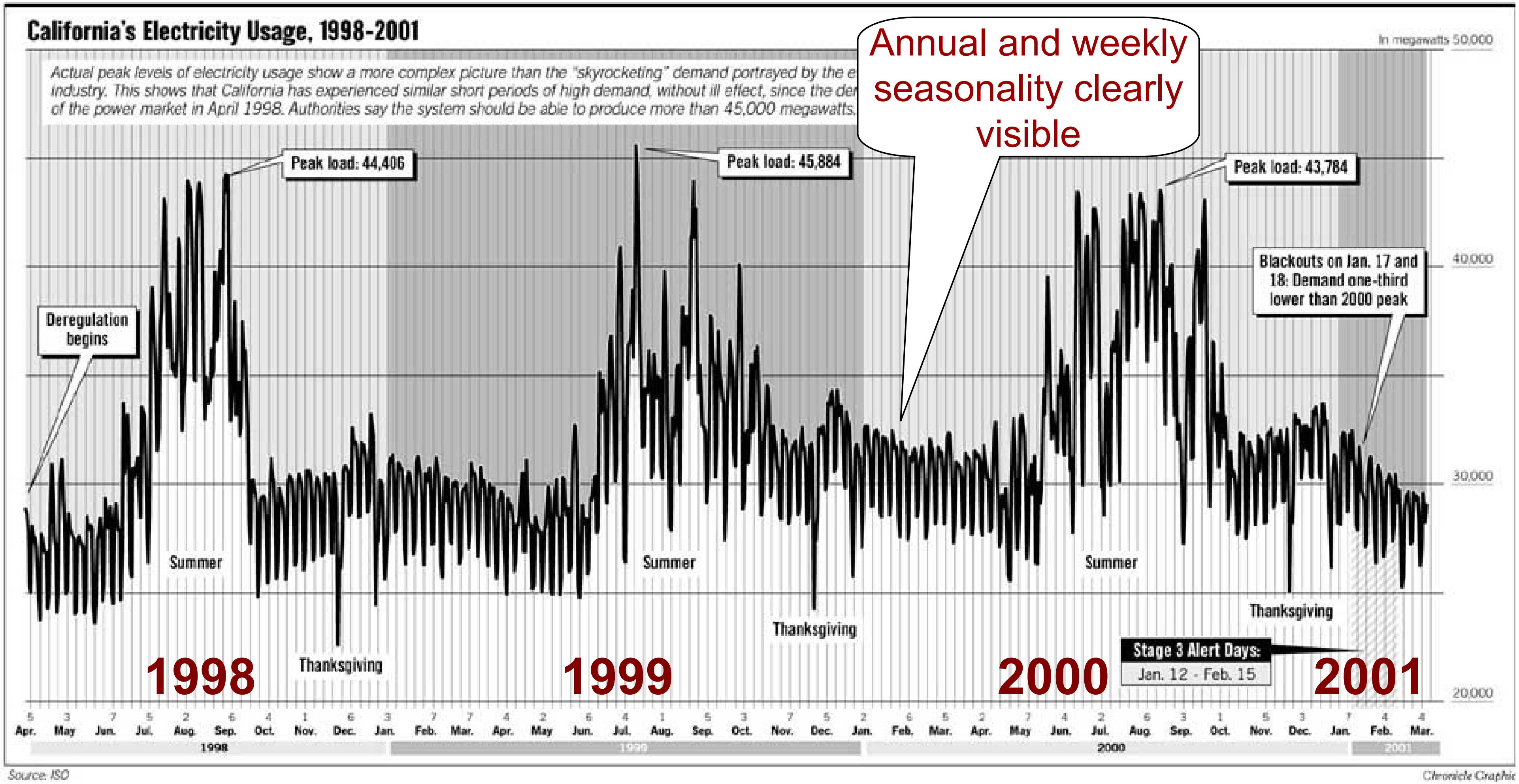
The making of California's electricity crisis



California crisis timeline

Date	**Event** (Prices are per MWh)
May-June 2000	ISO's real-time price reached $750 ten times
June 28	PX's day-ahead price (NP15) reached $1,099
July 1	CAISO lowers the price cap from $750 to $500
Aug. 7	CAISO further reduced the price cap to $250
Nov. 1	FERC issued an order, proposing a "soft cap" of $150
Jan. 8, 2001	Gov. Gray Davis declared deregulation a "colossal and dangerous failure" and proposed state intervention
Jan. 11	CAISO issued first **Stage 3 alert**
Jan. 17-18	**Rolling blackouts**
Apr. 6	Pacific Gas & Electric filed bankruptcy seeking court protection; reported **$8.9 bln losses**

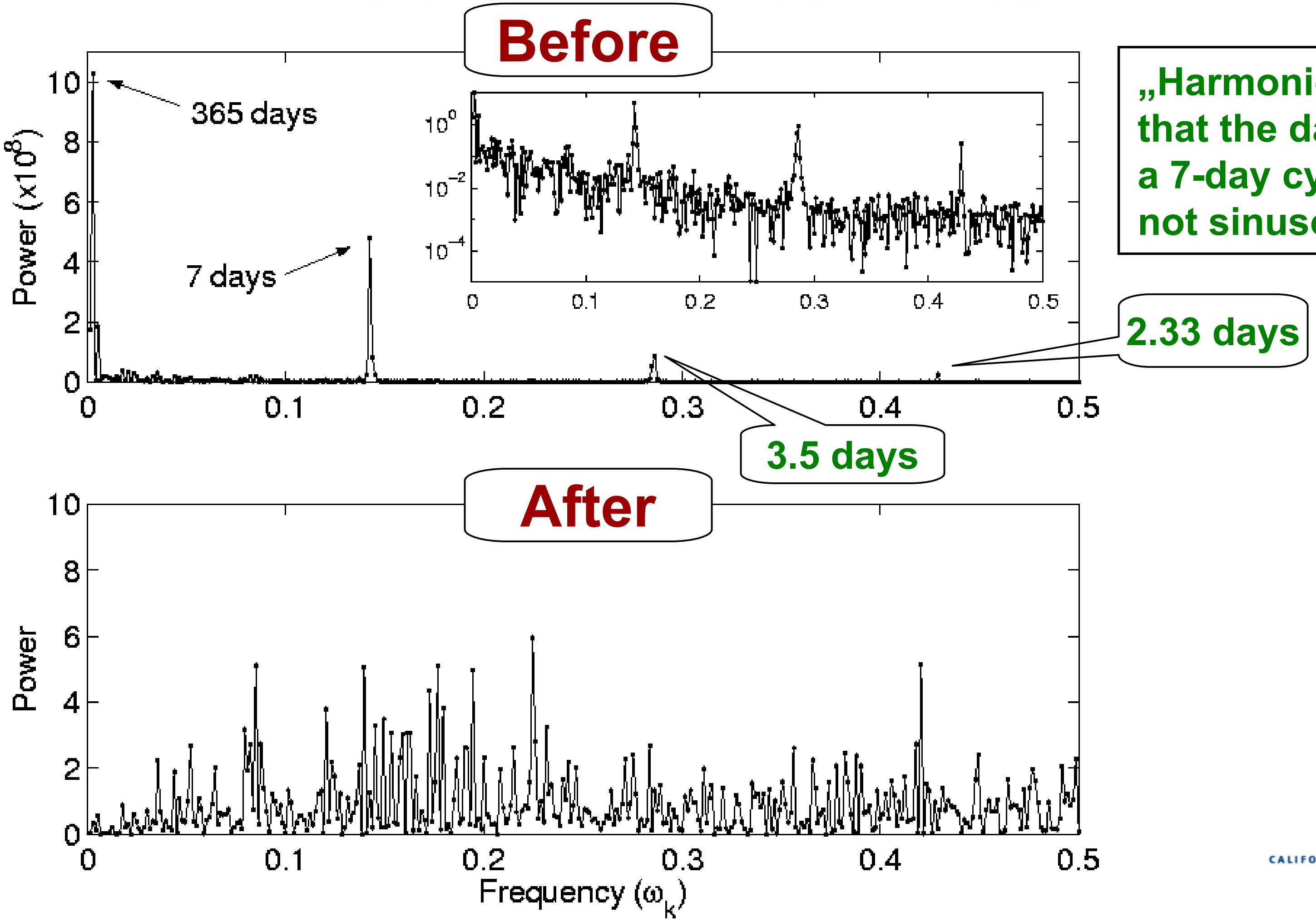
Was demand higher ?



Demand forecasting

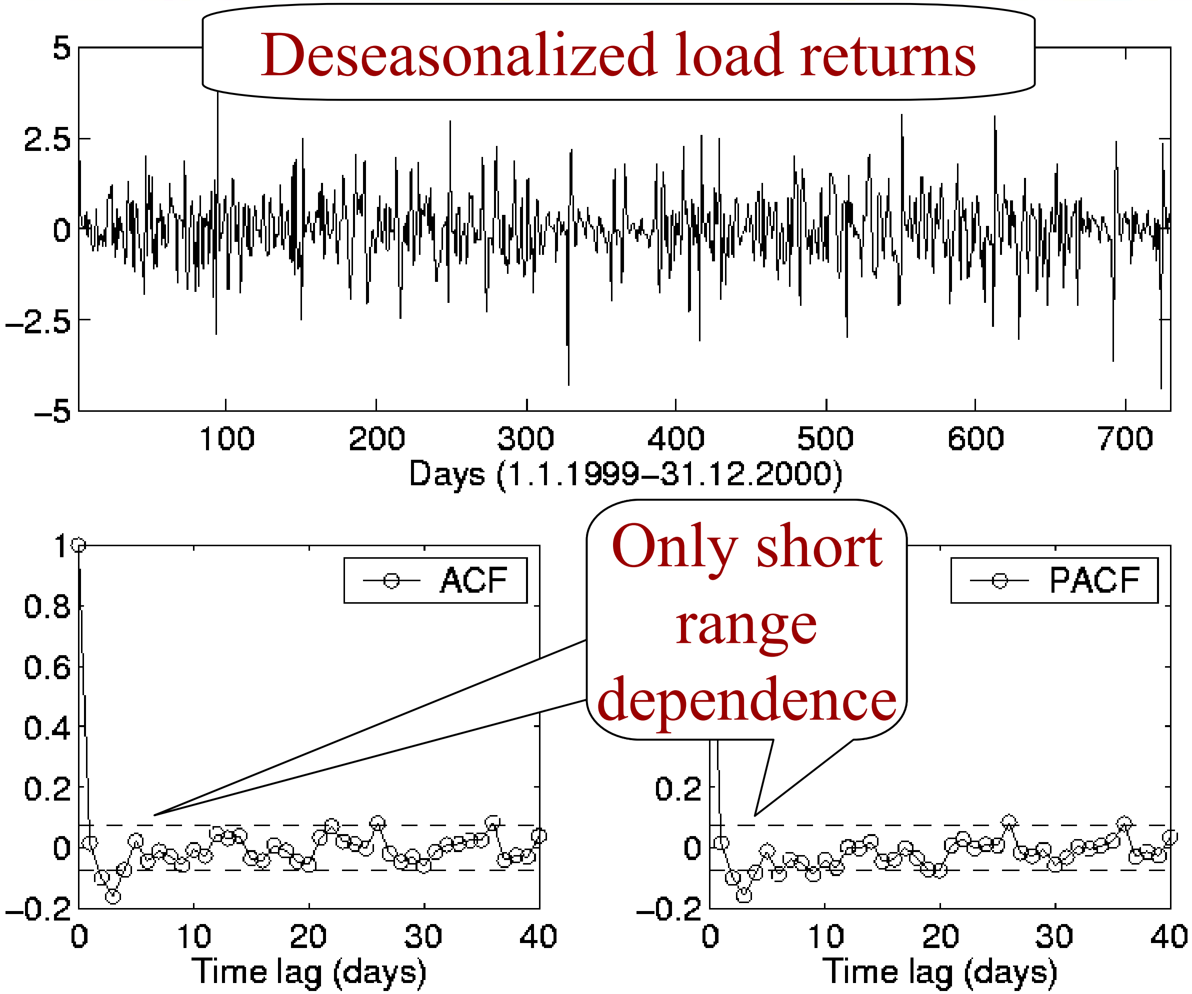
- Detecting seasonality
  - correlation, spectral analysis
- ☞ Removing seasonality and ARMA modeling
  - differencing, moving average method, seasonal volatility technique, fitting a sum of sinusoids
- ☞ Seasonal ARIMA (SARIMA) modeling
- Detecting periodic correlation
  - *see poster by Ewa Broszkiewicz et al.*
- ☞ Periodic ARMA (PARMA) modeling

CalPX load: periodogram before and after seasonality reduction



„Harmonics" indicate that the data exhibits a 7-day cycle, which is not sinusoidal

Deseasonalized load returns can be modeled by ARMA time series



ELSEVIER

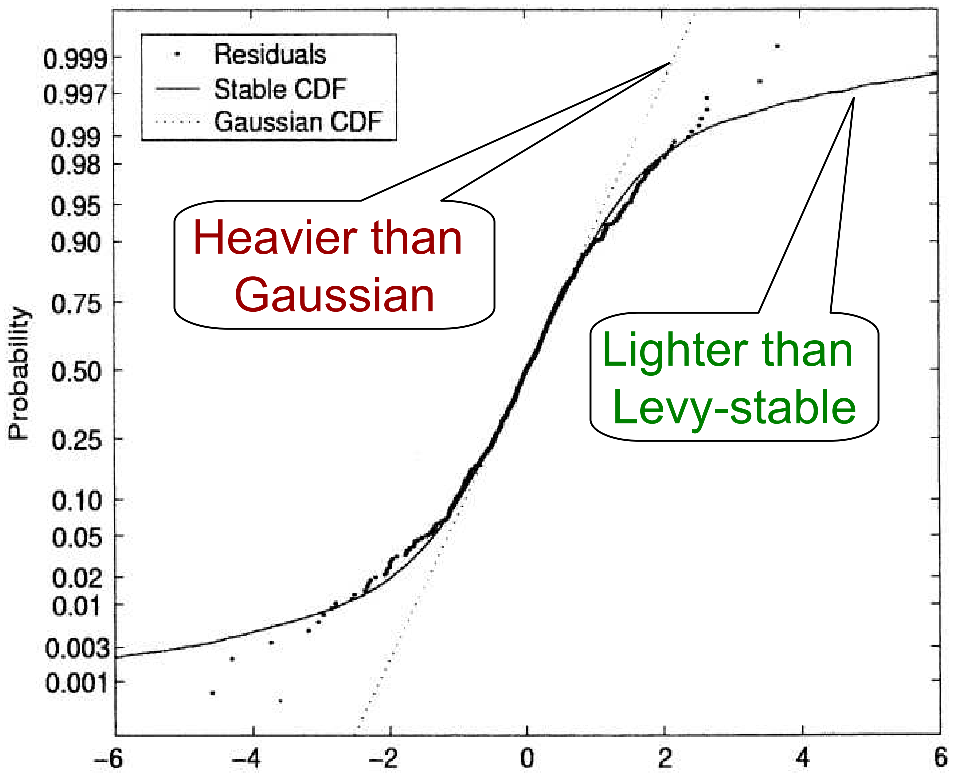
Signal Processing 82 (2002) 1903–1915

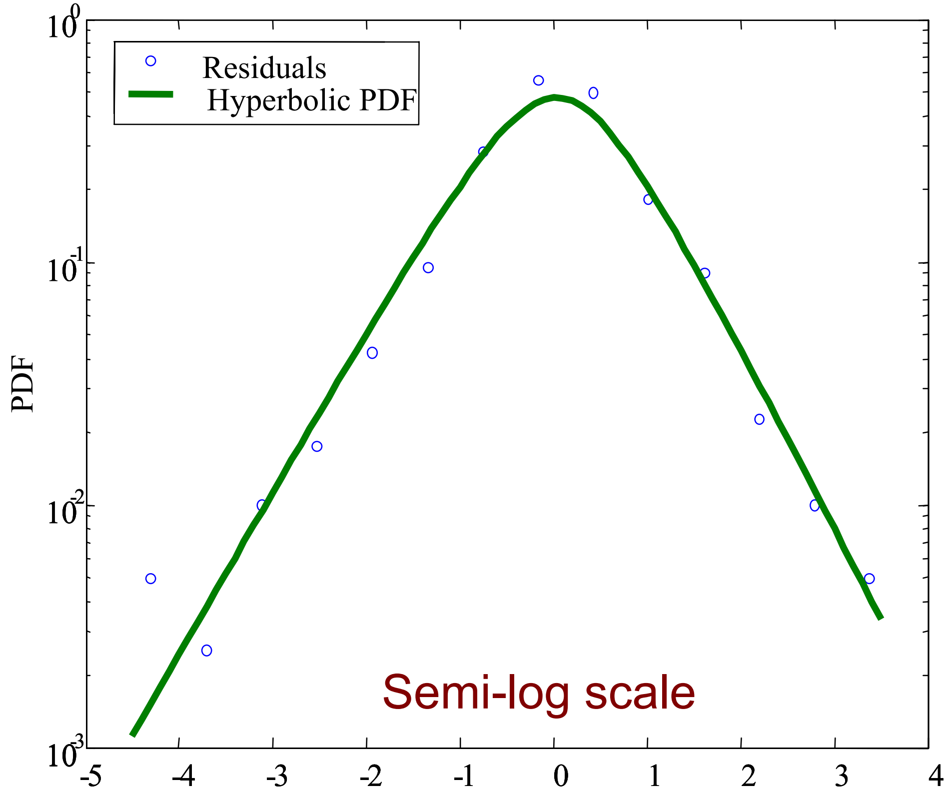
SIGNAL PROCESSING

www.elsevier.com/locate/sigpro

Modeling electricity loads in California: ARMA models with hyperbolic noise

J. Nowicka-Zagrajek[a,*,1], R. Weron[b,1]





ARMA models with hyperbolic noise cont.

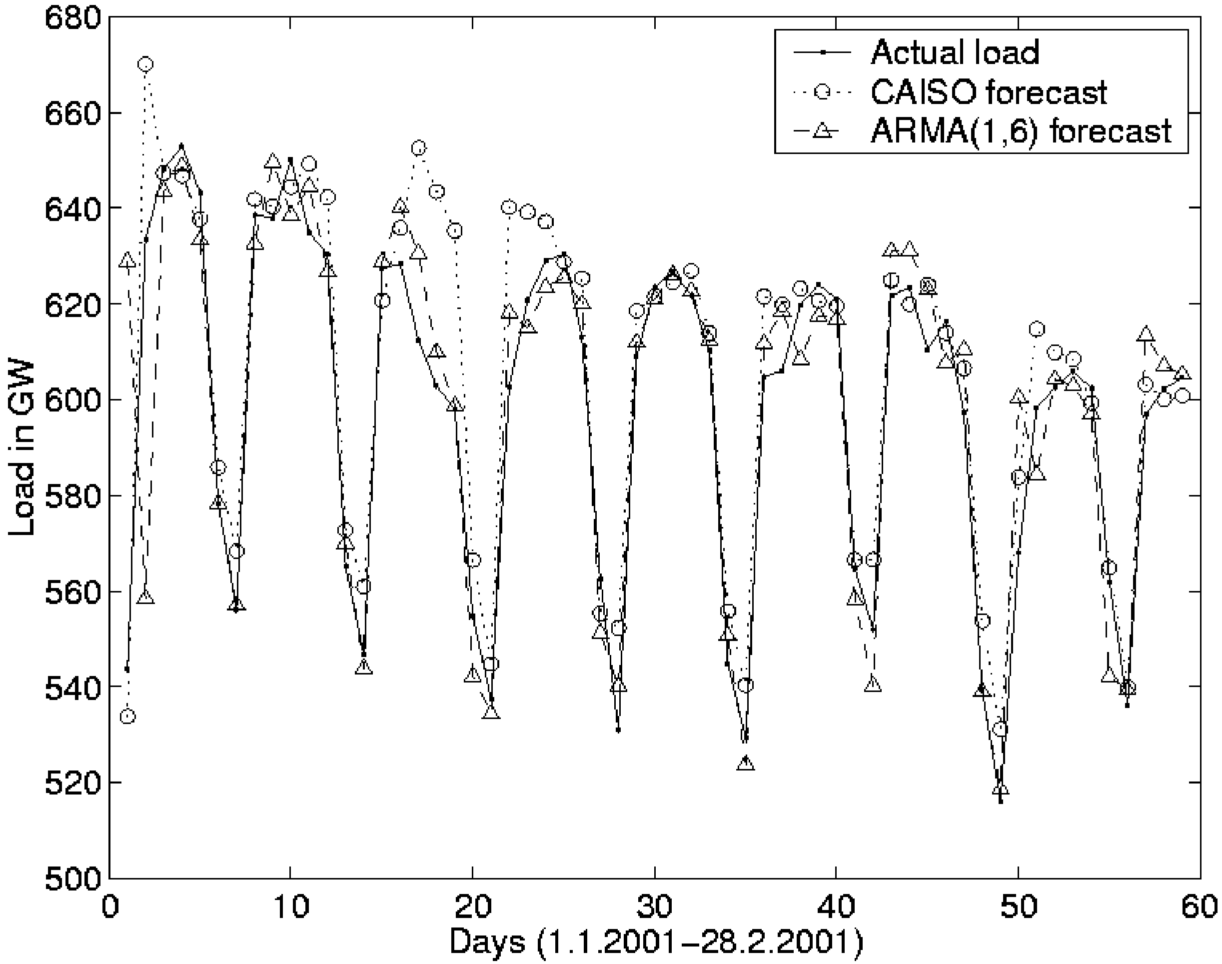
$$f(x;\alpha,\beta,\delta,\mu)$$

$$=\frac{\sqrt{\alpha^2-\beta^2}}{2\alpha\delta K_1(\delta\sqrt{\alpha^2-\beta^2})}\exp\{-\alpha\sqrt{\delta^2+(x-\mu)^2}$$

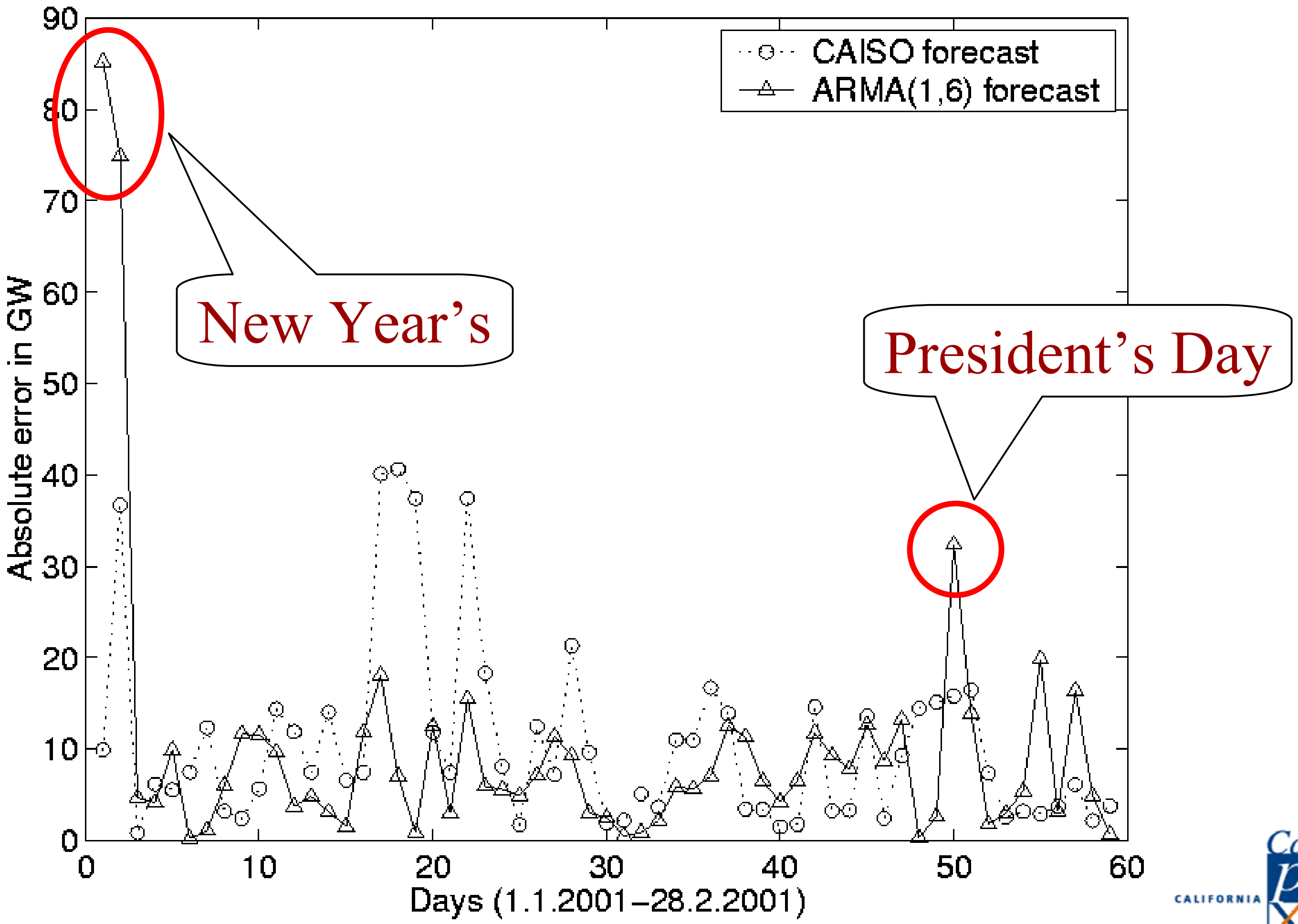
$$+\beta(x-\mu)\}, \qquad (13)$$

where $\delta > 0$ is the scale parameter, $\mu \in R$ is the location parameter and $0 \leqslant |\beta| < \alpha$. The latter two parameters—α and β—determine the shape, with α being responsible for the steepness and β for the skewness.

Actual load and day-ahead out-of-sample forecasts: 1-2.2001



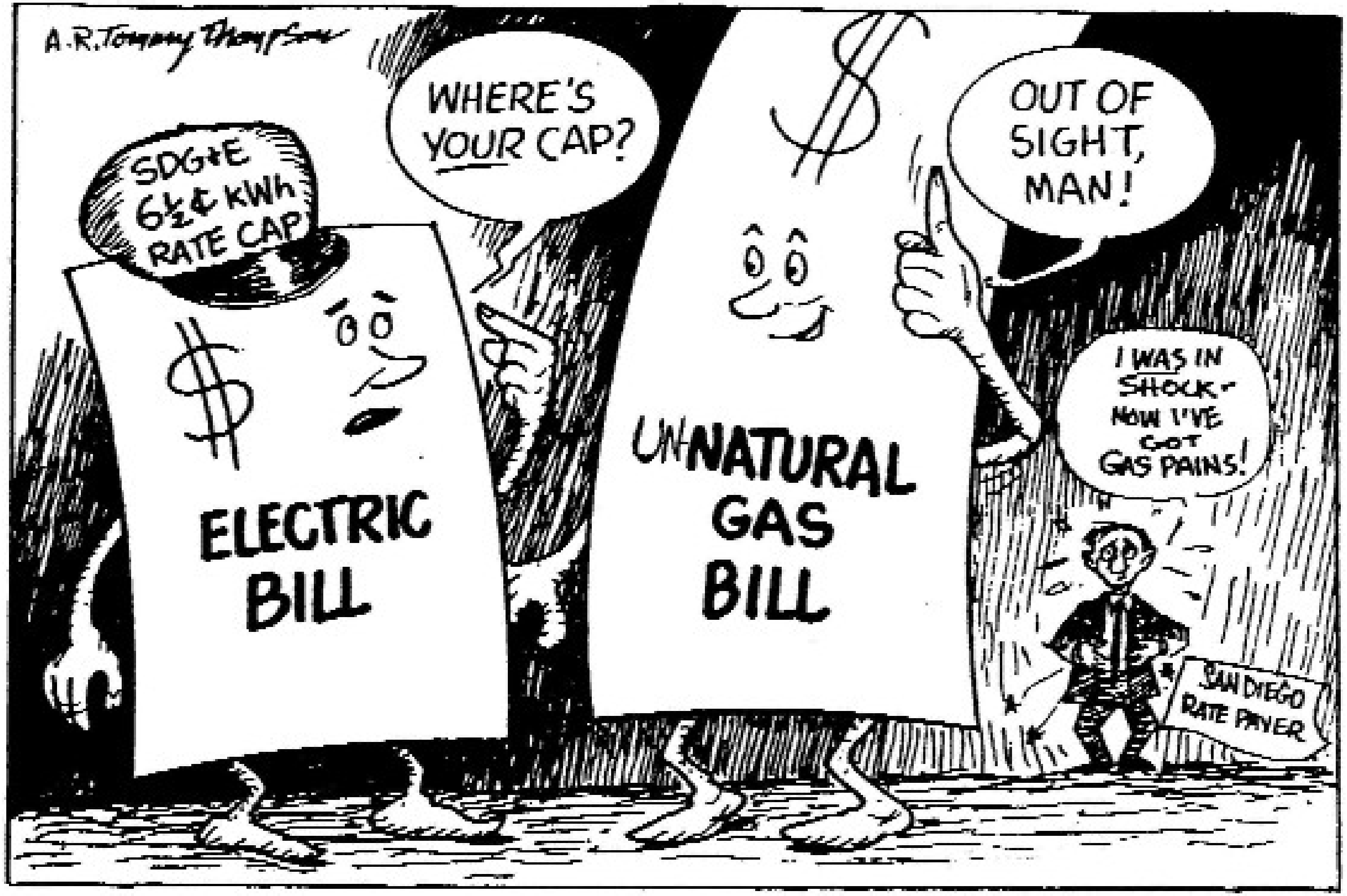
Errors of the day-ahead out-of-sample forecasts: 1-2.2001



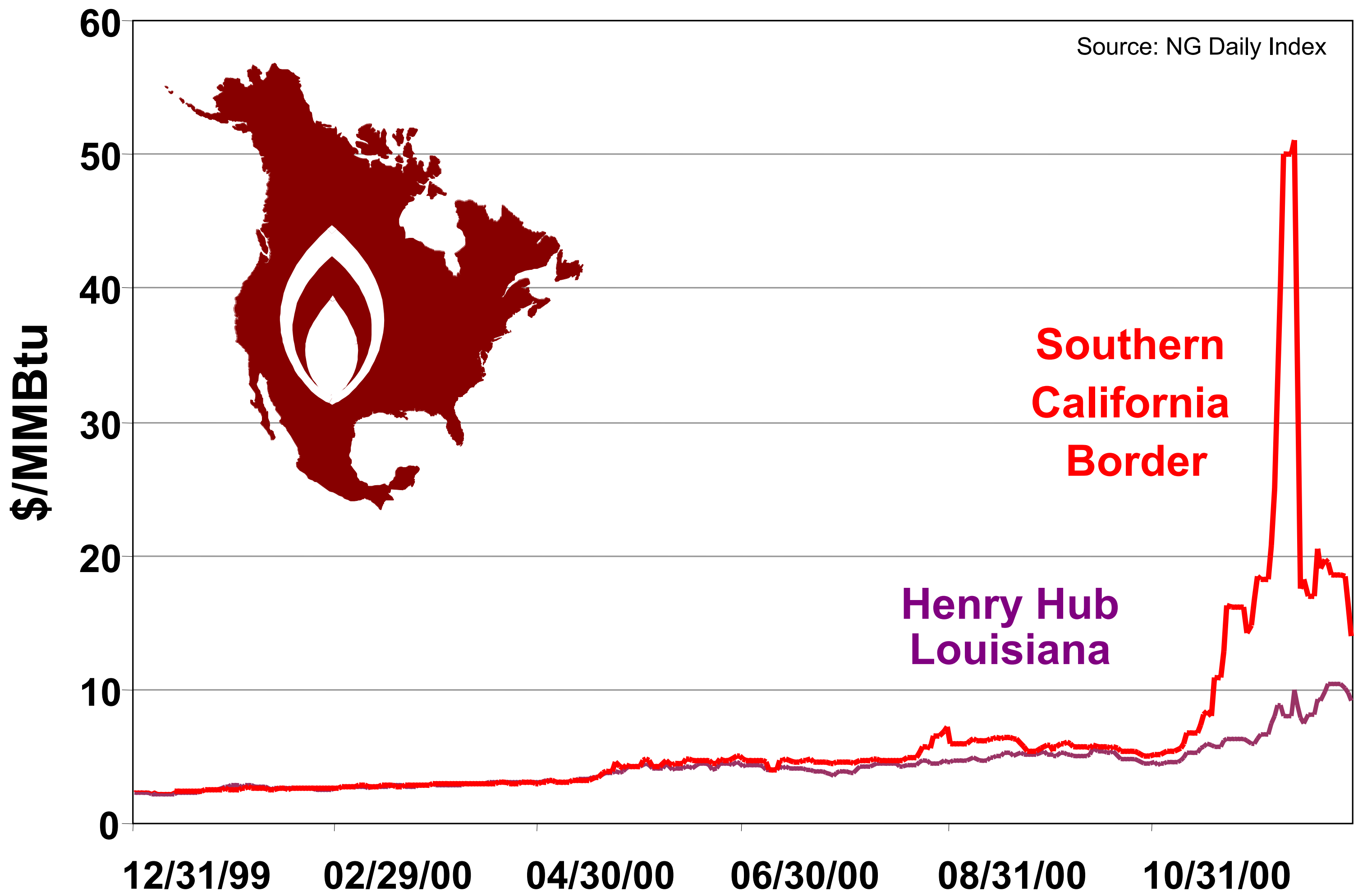
Errors of the day-ahead out-of-sample forecasts: 1-2.2001

Forecasting approach			
Error	CAISO	ARMA(1,6)	Adaptive ARMA
January 1–February 28			
MSE	208.34	304.14	318.50
MAE	10.52	9.86	9.87
MAPE (%)	1.7799	1.6642	1.6682
January 3–February 28			
MSE	190.28	89.00	88.36
MAE	10.08	7.39	7.31
MAPE (%)	1.7087	1.2401	1.2282

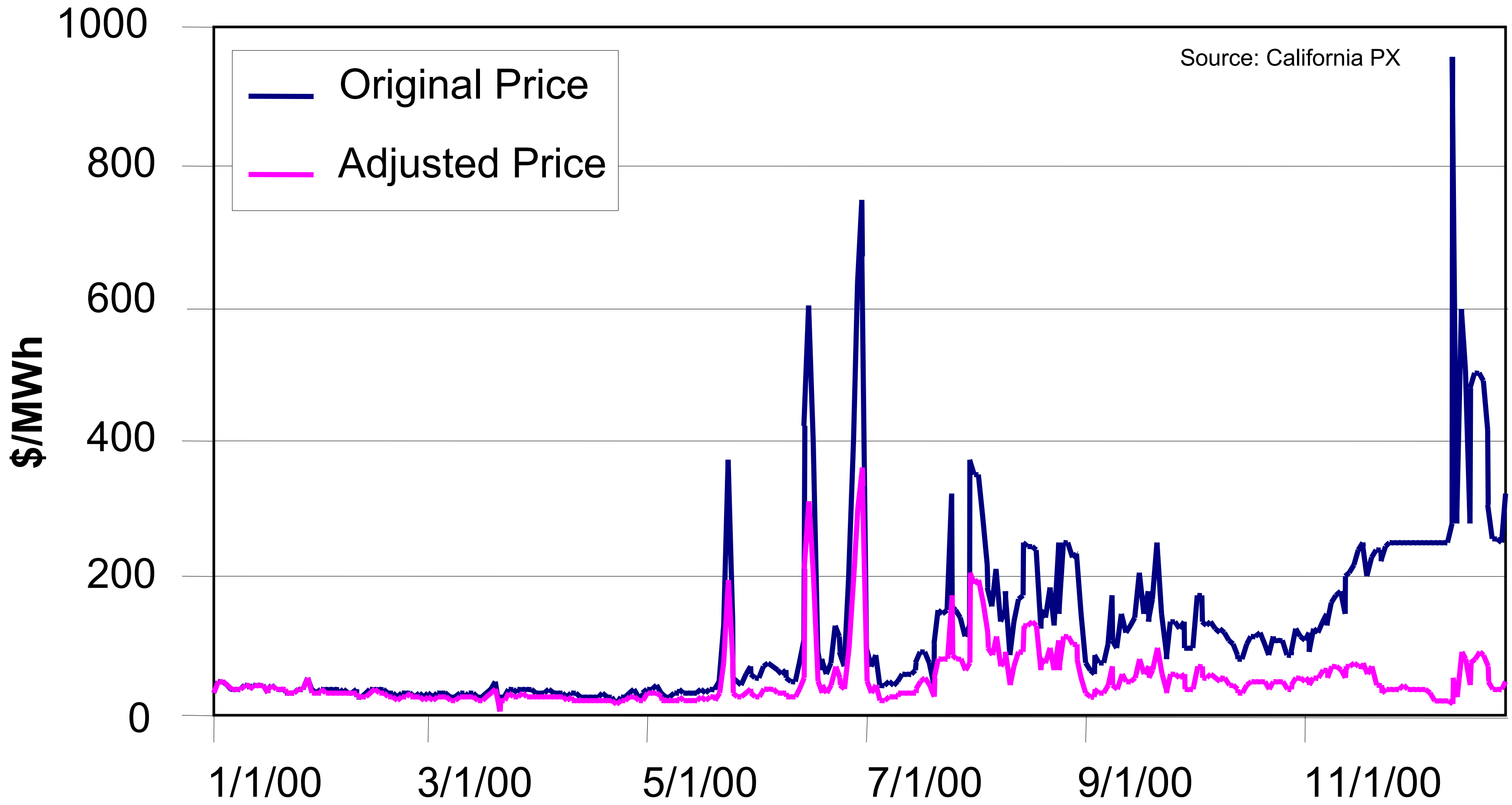
If it wasn't the demand then maybe it were the "gas pains"!



Natural gas prices

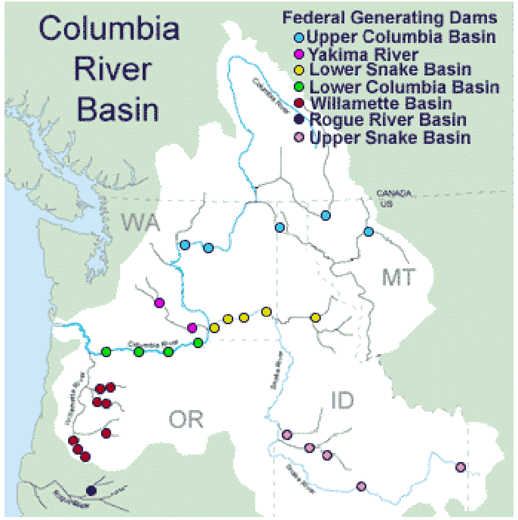


Electricity prices in 2000 – nominal and gas price adjusted



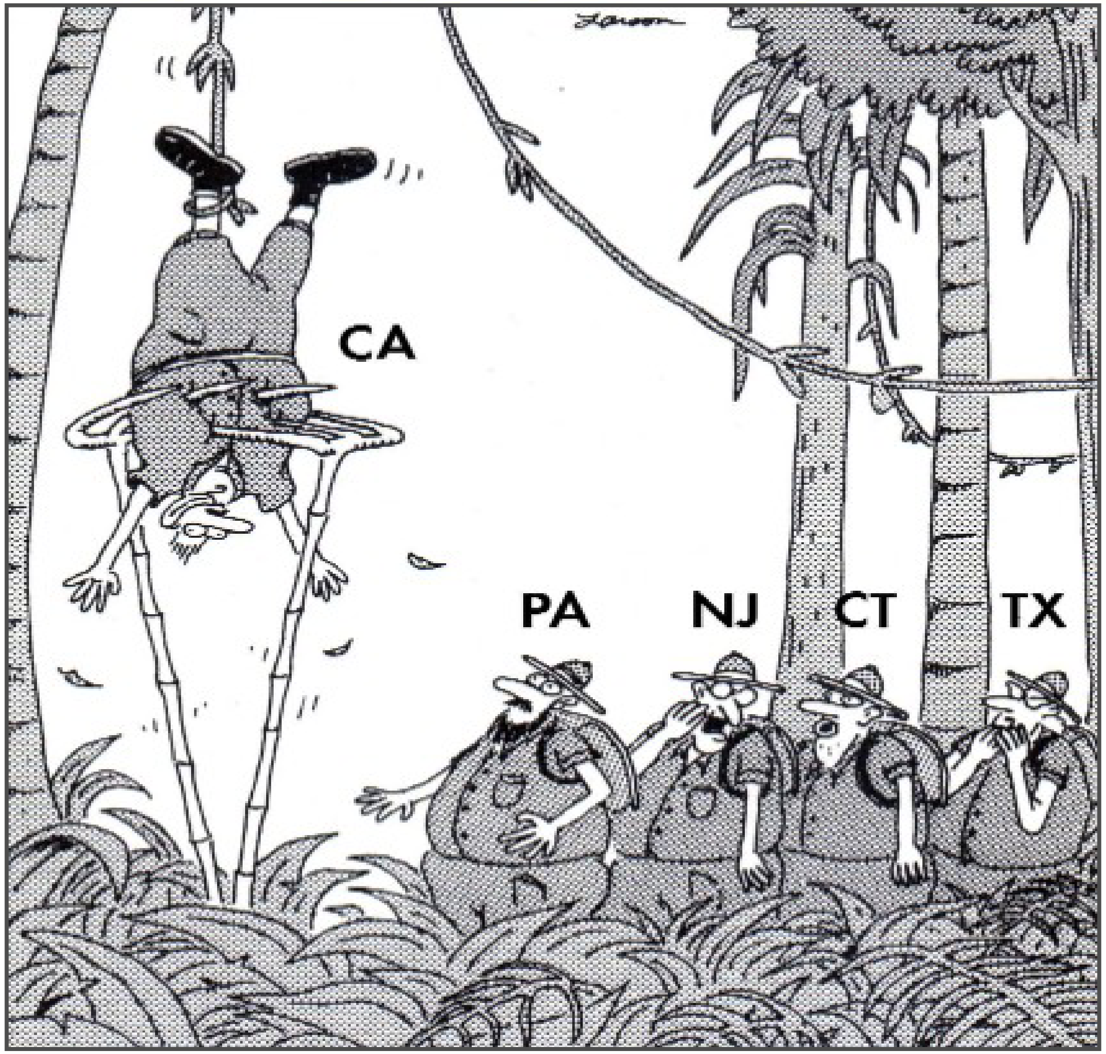
Other causes

- Precipitation in Columbia river basin lower by 40%
- Little generation investment in the last 10 years
- Execution of **market power** by the producers
  - bidding strategies, cooperative "games"
  - ☞ *see poster by Agnieszka Wyłomańska*



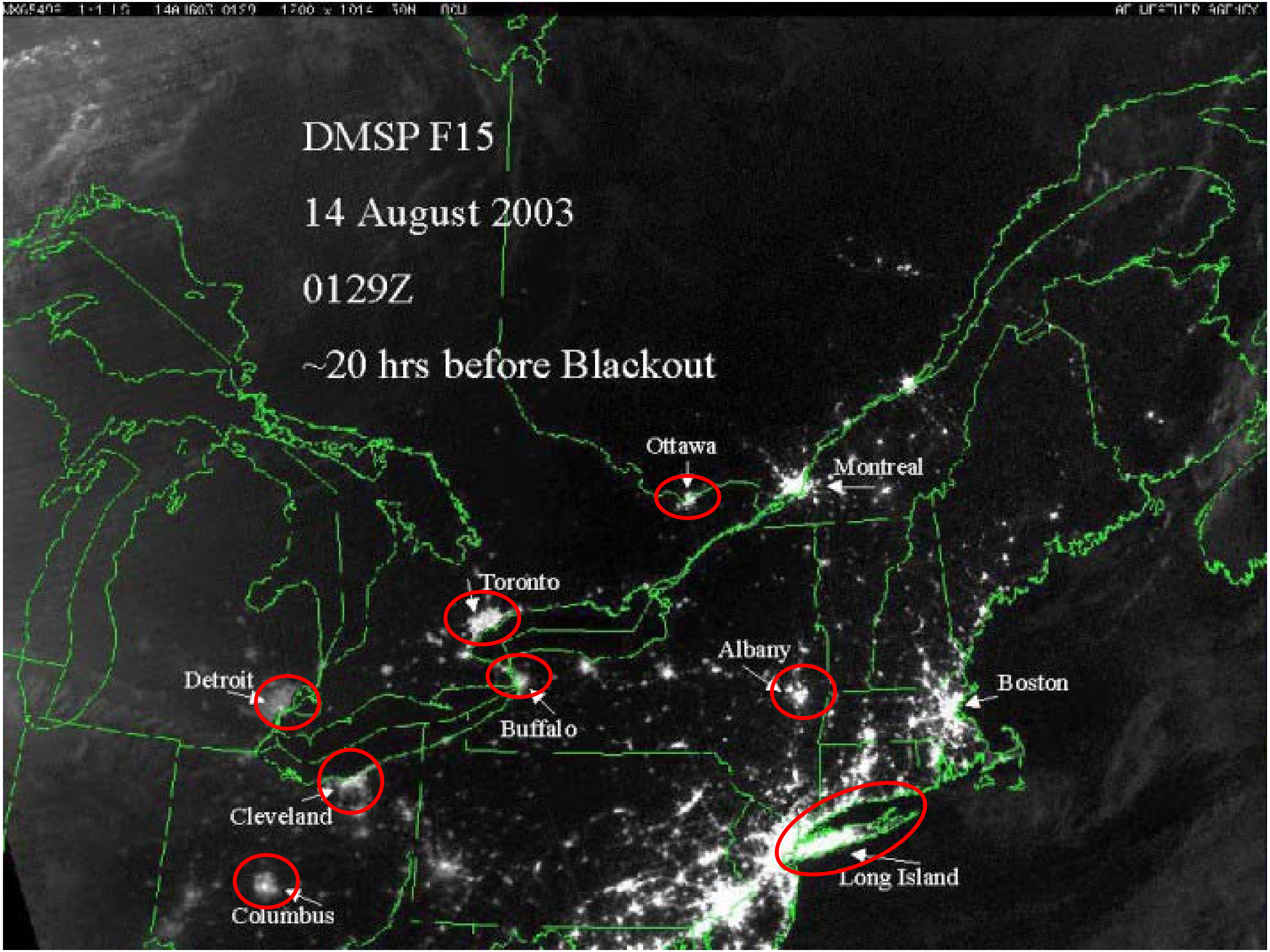
Map courtesy of the Bonneville Power Administration.

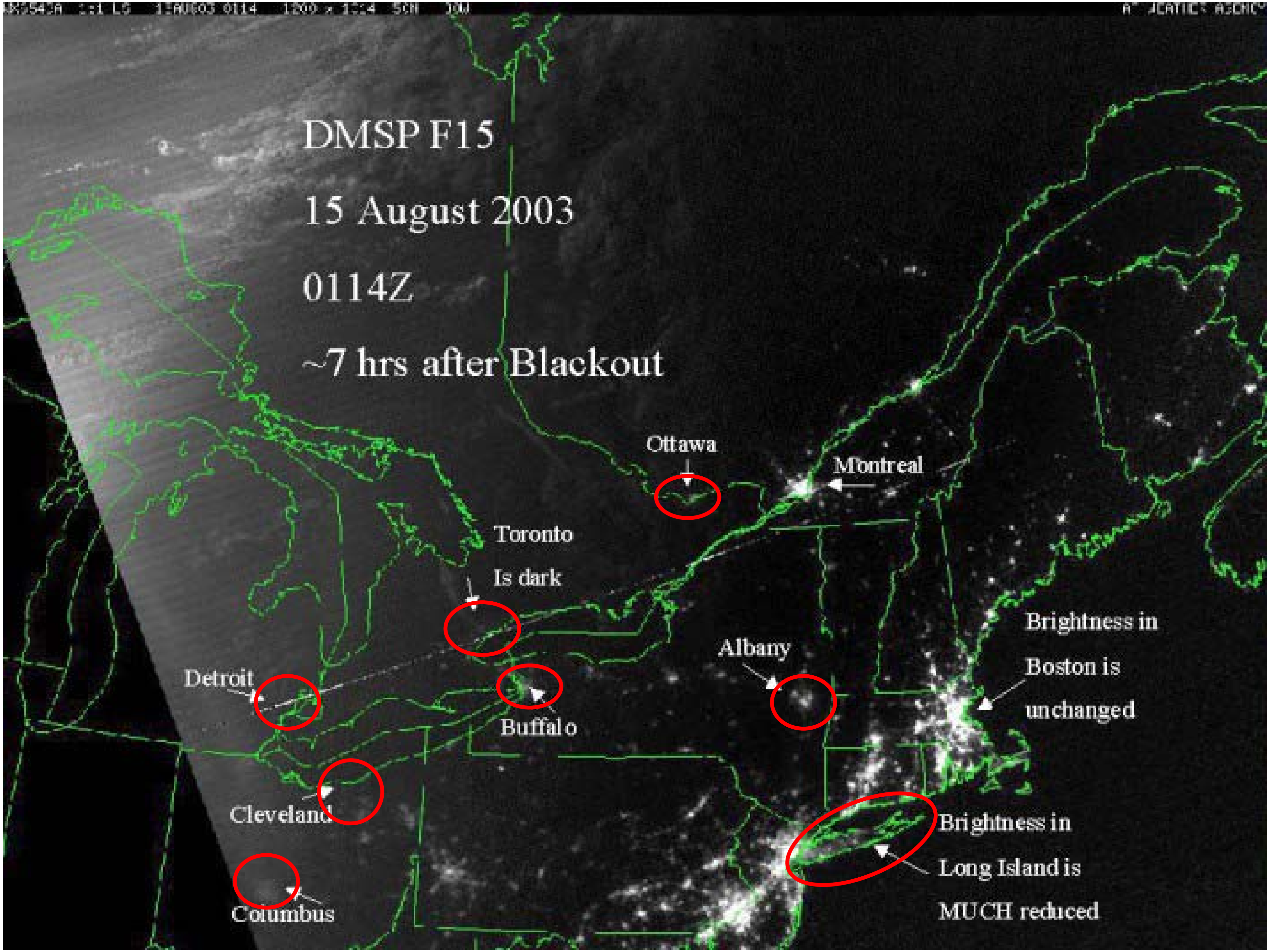
“That’s why I never walk in front”



BLACKOUTS

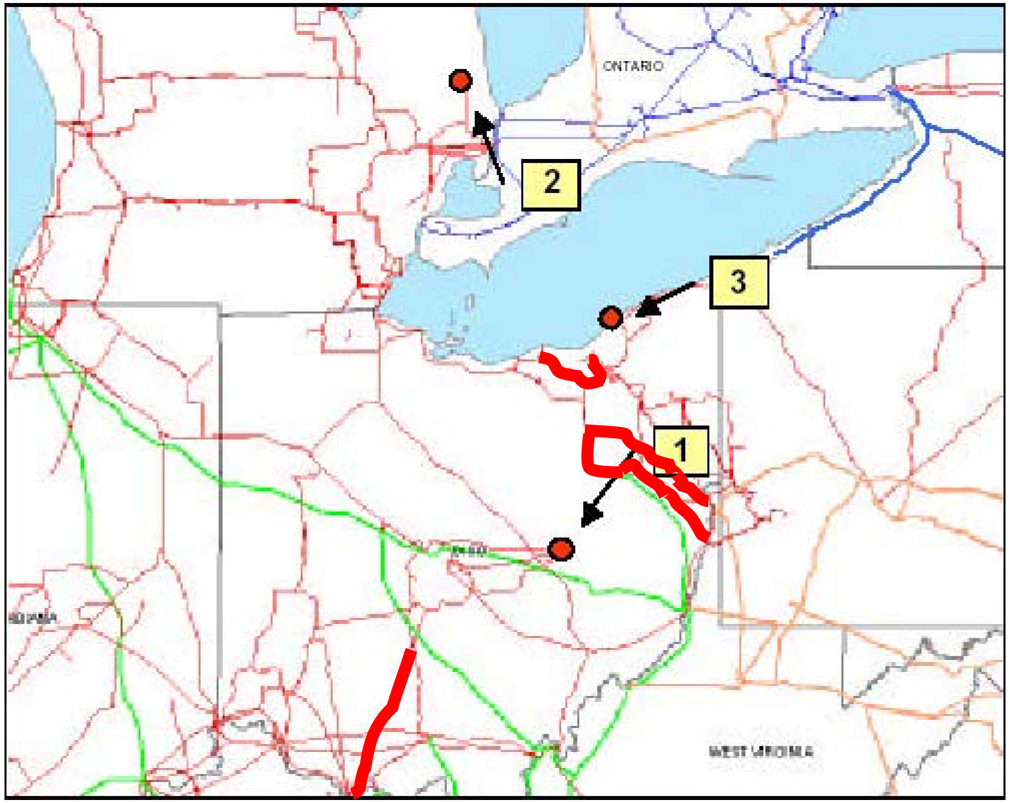
- System load (throughput)
  - optimized to get the maximum out of the system
  - high load means small operating margins
  - has impact on interactions and component failures
- Tradeoff between load and risk of failure
  - at system level
  - for system components


DMSP F15
14 August 2003
0129Z
~20 hrs before Blackout
Ottawa
Montreal
Toronto
Albany
Boston
Detroit
Buffalo
Cleveland
Long Island
Columbus

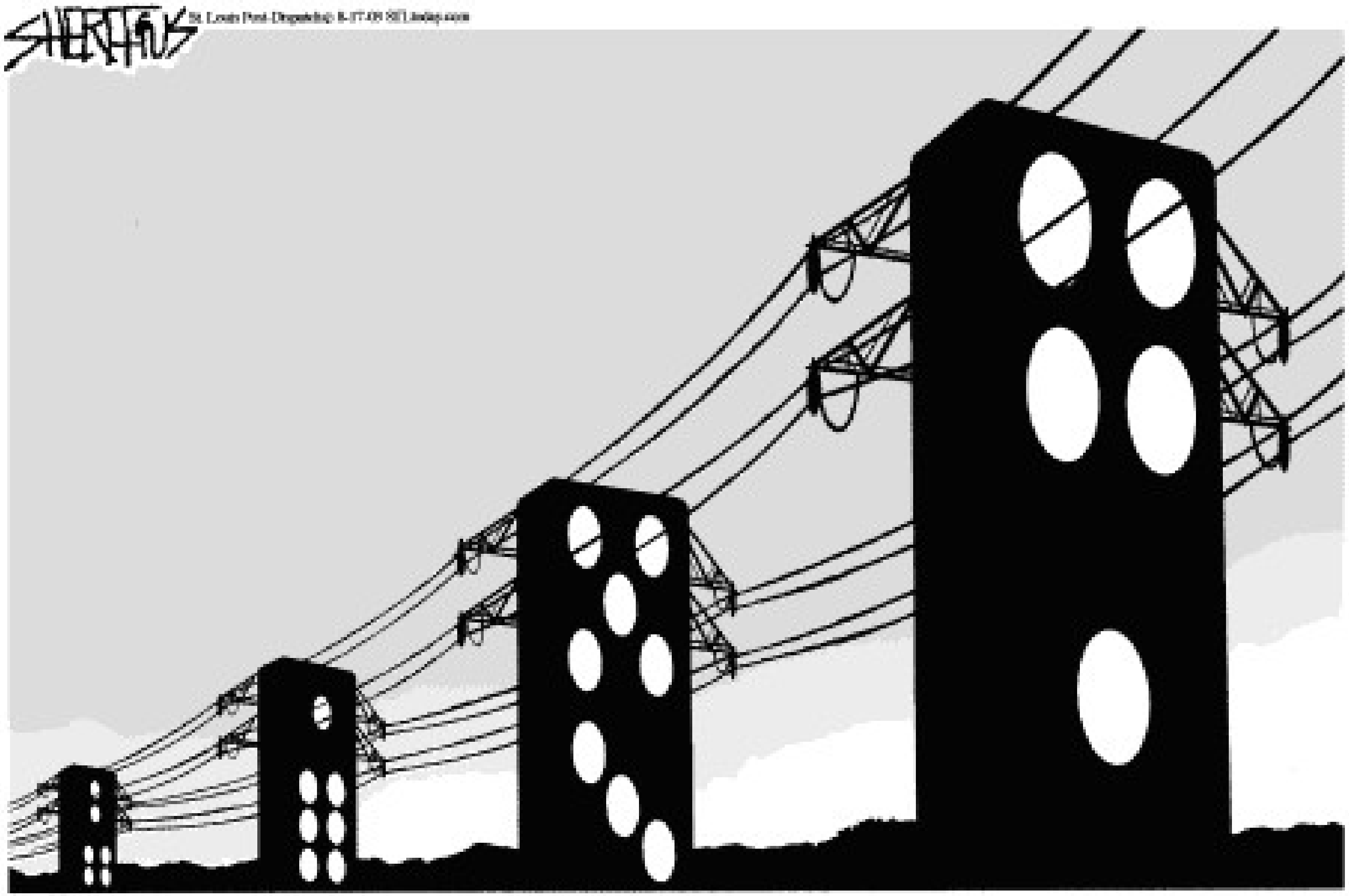

DMSP F15
15 August 2003
0114Z
~7 hrs after Blackout
Ottawa
Montreal
Toronto
Is dark
Detroit
Buffalo
Albany
Brightness in
Boston is
unchanged
Cleveland
Columbus
Brightness in
Long Island is
MUCH reduced

2003 Blackout timeline

- 12:05:44 – 1:31:34 PM: 3 generator trips (shutdowns) causing flow pattern changes
- 2:02 PM: transmission line disconnects in SW Ohio due to fire under the line
- 3:05:41 – 3:41:33 PM: transmission lines disconnect between E Ohio and N Ohio; reasons unknown
- 3:45:33 – 4:08:58 PM: remaining transmission lines disconnect from E into N Ohio

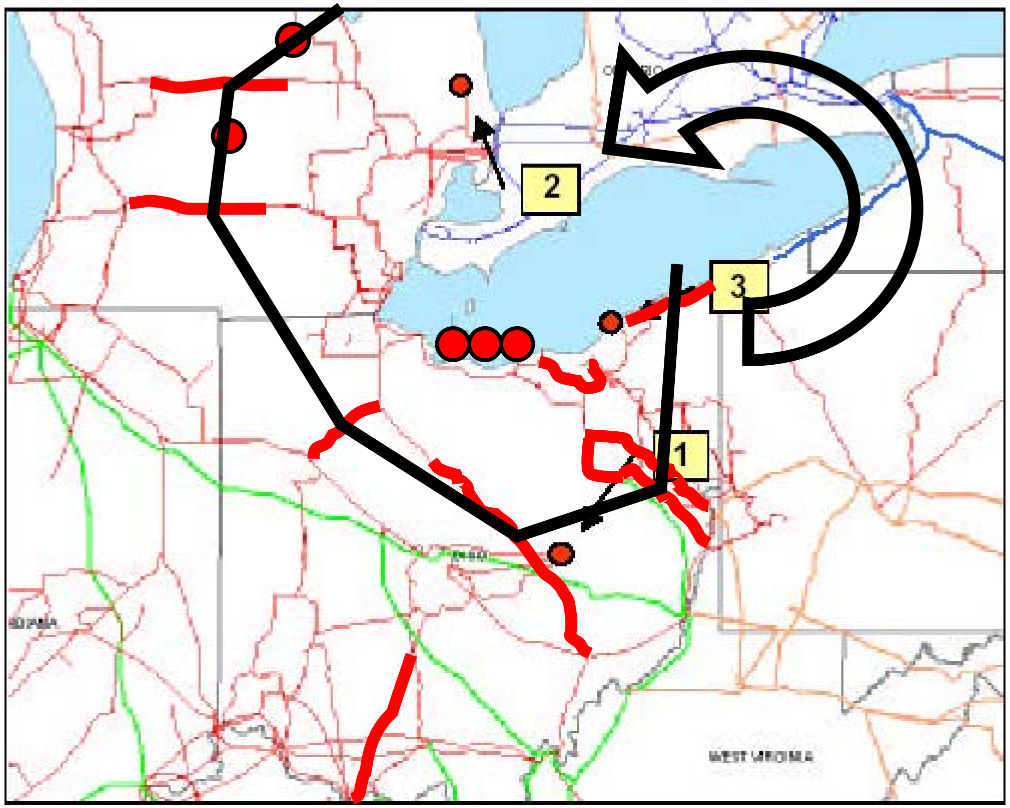


2003 Blackout
– the domino effect



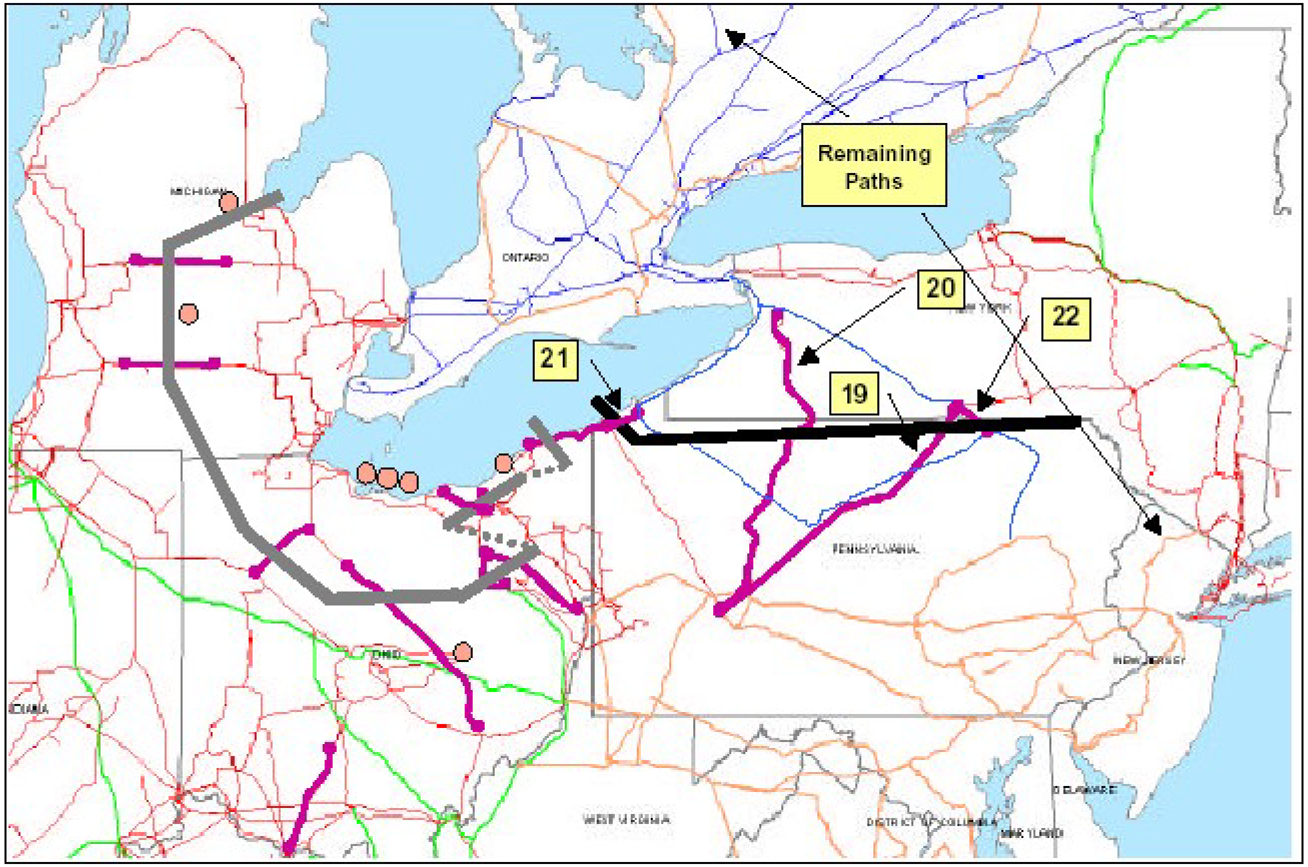
2003 Blackout timeline cont.

- 4:08:58 – 4:10:27 PM: transmission lines into NW Ohio disconnect, and generation trips in central Michigan
- 4:10:00 – 4:10:38 PM: lines disconnect across Michigan and N Ohio, generation trips off line in N Michigan and N Ohio, and N Ohio separates from Pennsylvania
- Power immediately reversed direction and began flowing in a giant loop counterclockwise from PA to NY to Ontario and into Michigan



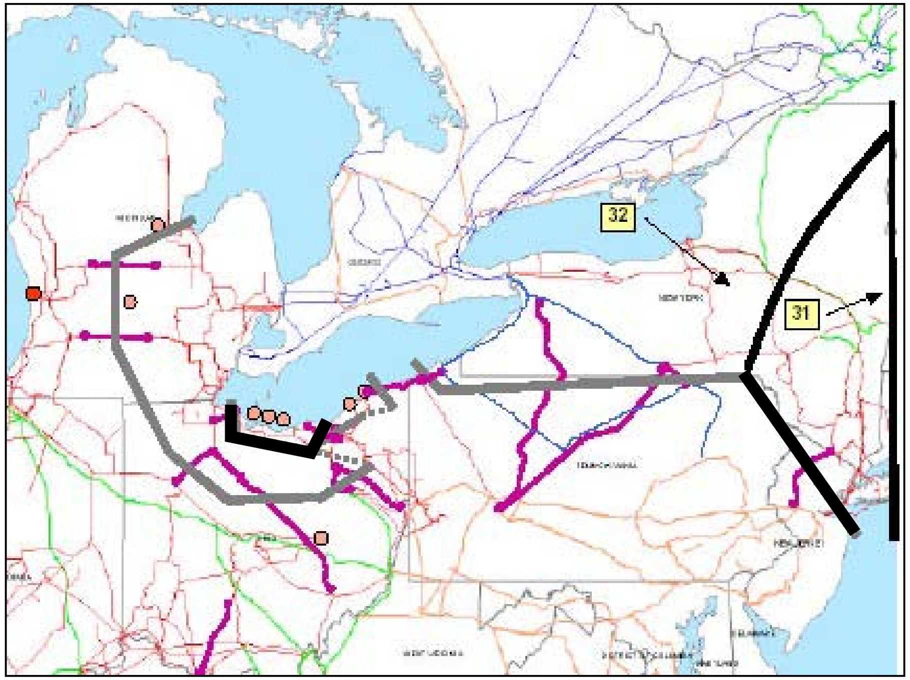
2003 Blackout timeline cont.

- 4:10:40 – 4:10:44 PM: four transmission lines disconnect between Pennsylvania and New York



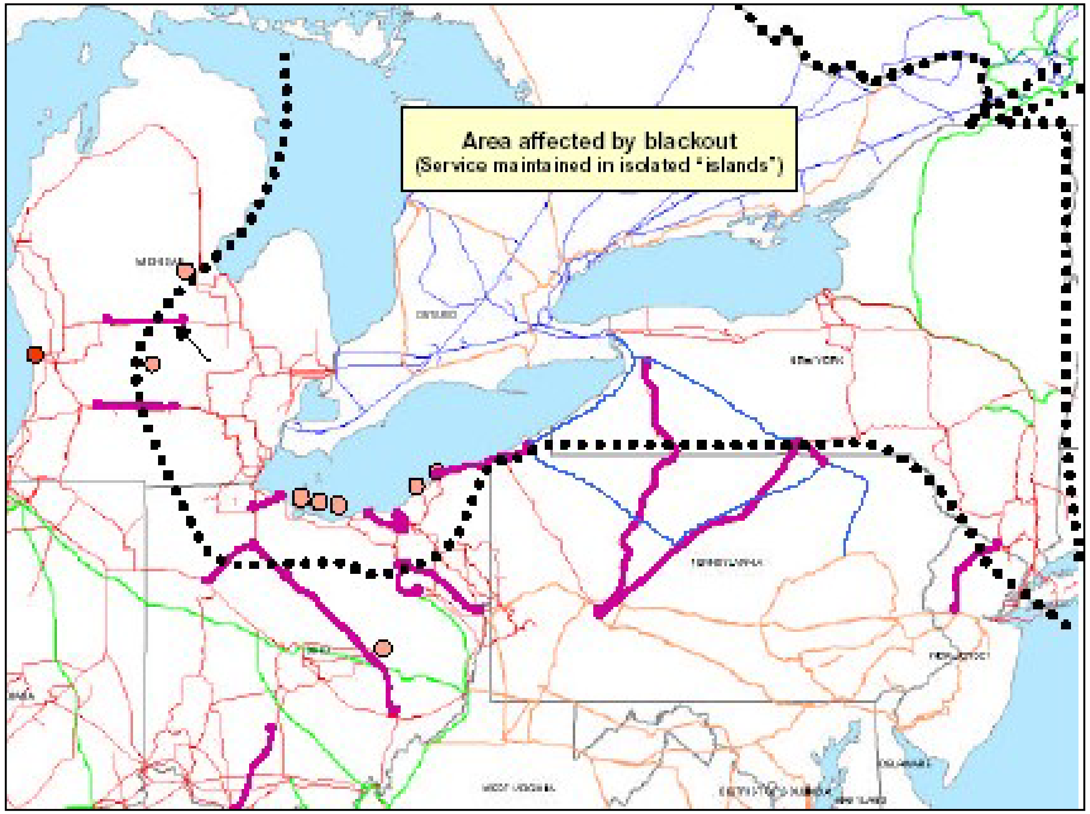
2003 Blackout timeline cont.

- 4:10:41 PM: line disconnects and generation trips in N Ohio
- 4:10:42 – 4:10:45 PM: trans-mission paths disconnect in N Ontario and New Jersey, isolating the NE portion of the Eastern Interconnection
- 4:10:46 – 4:10:55 PM: New York splits east-to-west; New England (except SW Connecticut) and the Maritimes separate from New York and remain intact

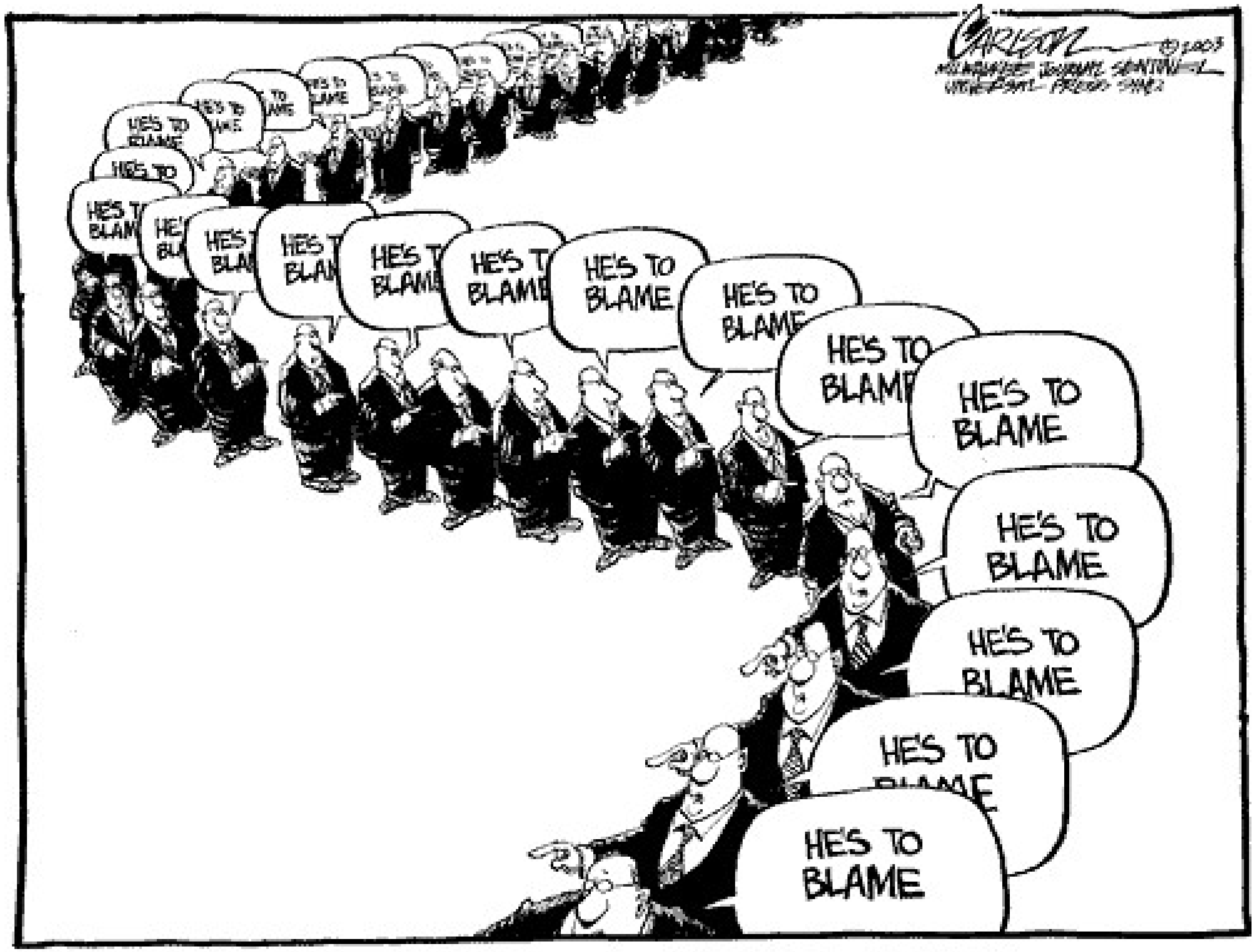


2003 Blackout timeline cont.

- 4:10:50 – 4:11:57 PM: Ontario separates from New York west of Niagara Falls and west of St. Lawrence; SW Connecticut separates from New York and blacks out
- 4:13 PM: cascading sequence essentially complete
- **More than 60 mln customers affected !**



2003 Blackout – the cascade effect

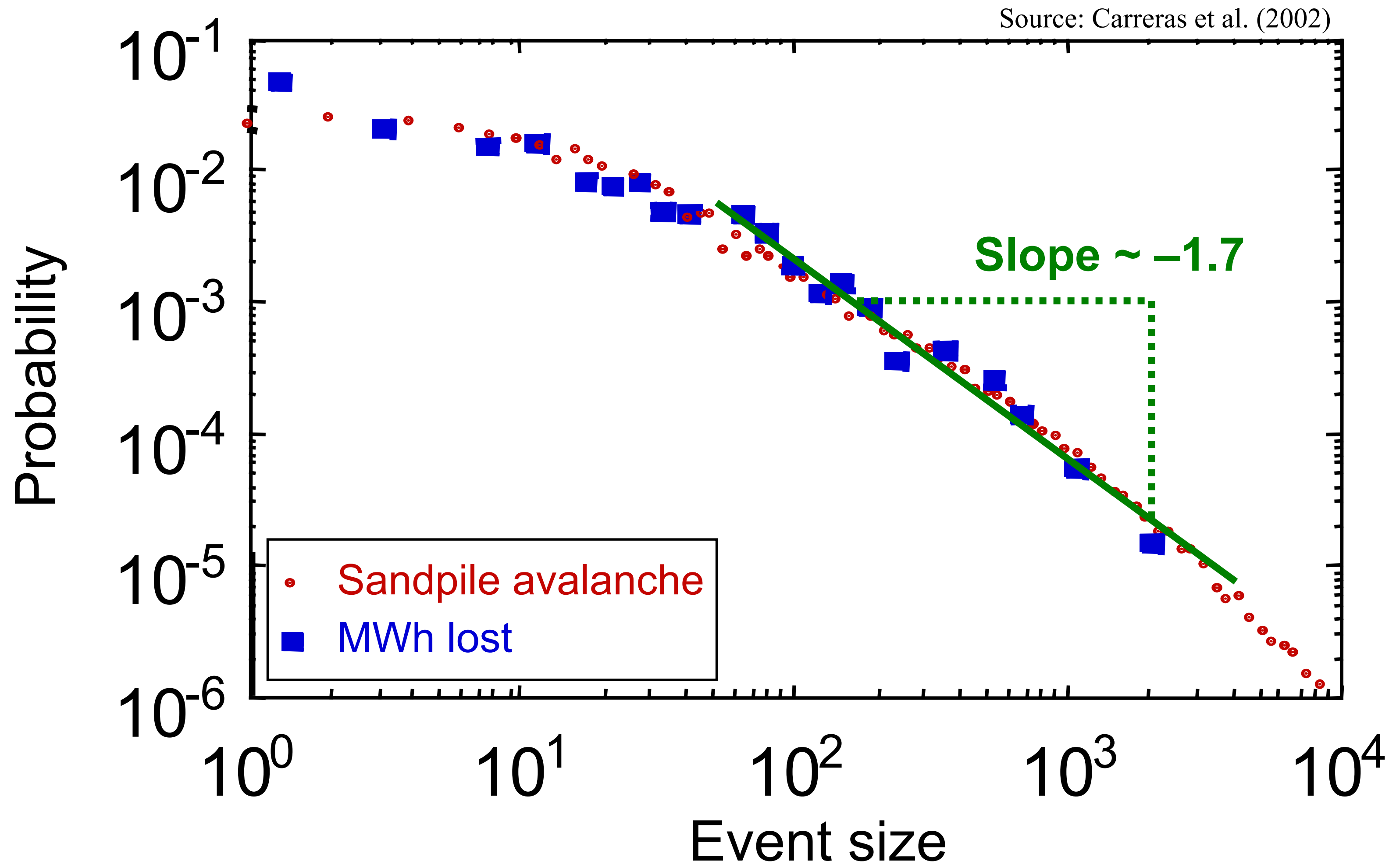


BLACKOUT OF '03 — The "CASCADE EFFECT"

Modeling blackouts

- North American Electricity Reliability Council (NERC) data
  - Analyzed by Carreras, Dobson, Newman & Poole
  - 15 years of data (1984-98)
  - 427 blackouts
  - on average 28.5 per year, waiting time of 12 days
- Three measures of blackout size
  - energy unserved (MWh)
  - amount of power lost (MW)
  - number of customers affected

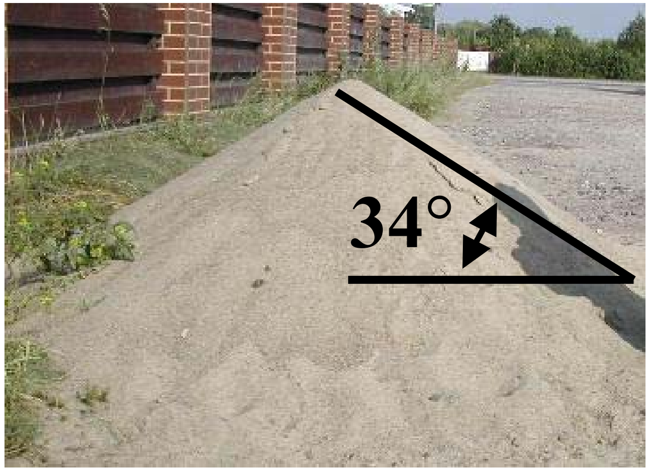
What is the distribution of blackout sizes ?



Modeling blackouts cont.

- There seems to be a critical loading at which
  - sharp increase in average number of failures is observed
  - power tail distribution of blackout sizes forms

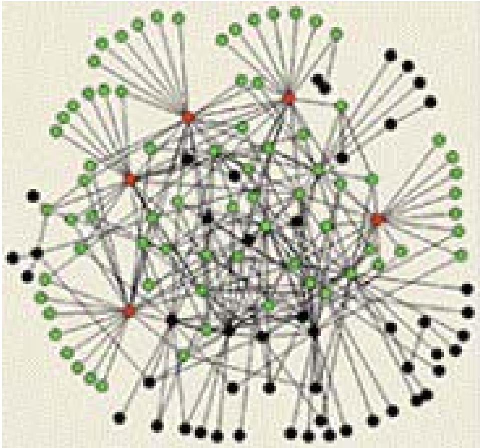
☞ power system has **Self-Organizing Criticality** (SOC) dynamics ?!



☞ cascade models

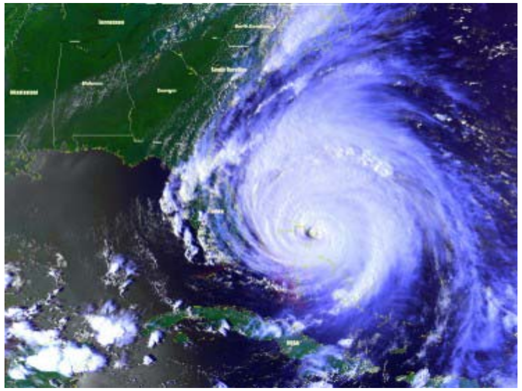
Modeling blackouts cont.

- Waiting times have exponential tails
  - blackouts can be modeled by a **Poisson process**
    - ☞ like the **risk process** in insurance
    - ☞ **Extreme Value Theory**
- Power system is a network
  - What type of a network should it be?
  - Can we construct such networks?
  - What is the critical loading?



WEATHER

- Important for energy at a range of time scales
- Daily
  - Highly anomalous temperatures at a location
  - Widespread anomalous temperatures
- Multiple days
  - Hurricanes
  - Persistent heat events



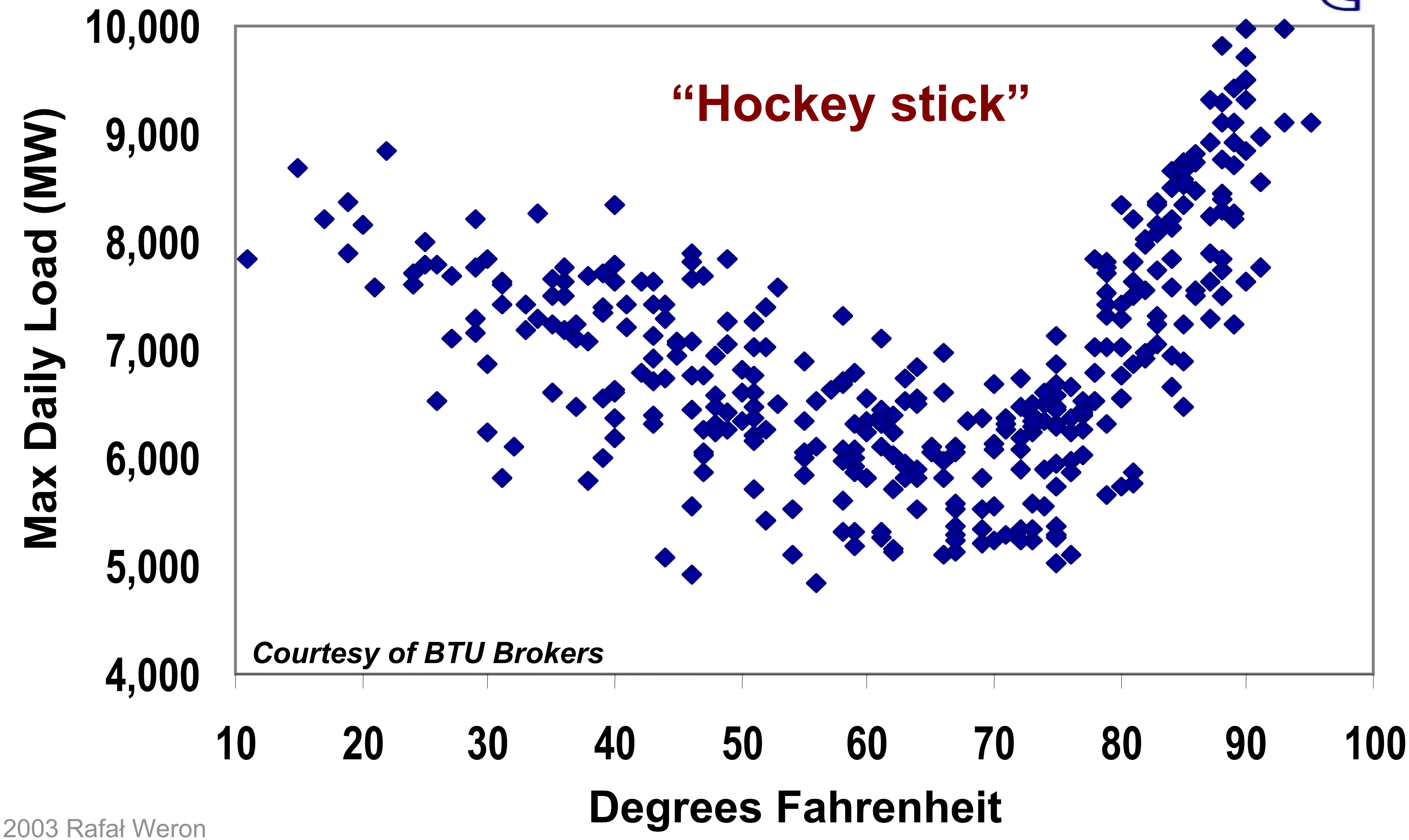
- Seasonal
  - Much colder winter than normal
  - Excessively wet/dry winter in Scandinavia, Pacific Northwest

Role of weather in power sector

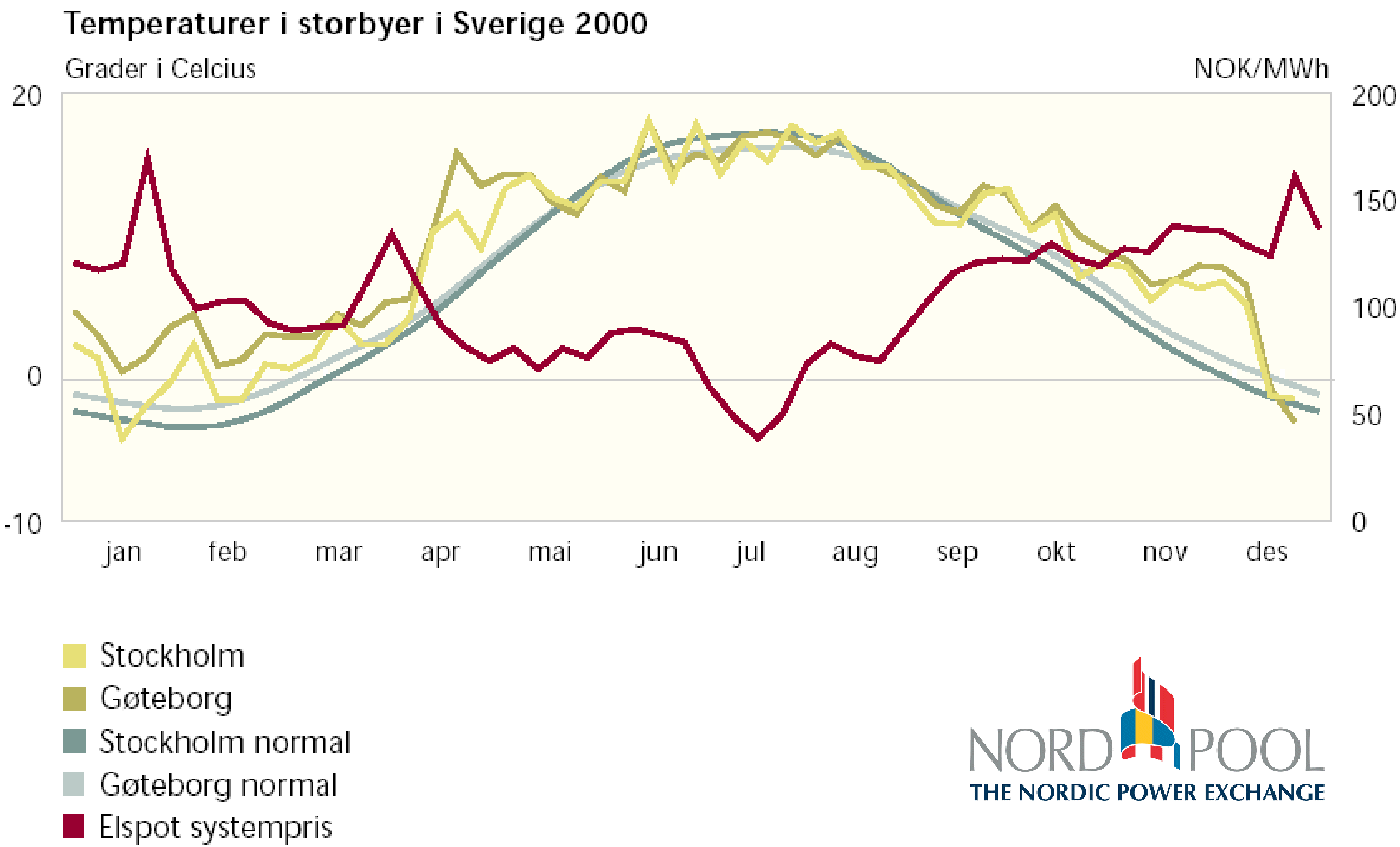
- Electricity – Demand
  - Weather is a measure of demand
    - Quasi-linear for non-extreme
    - “Hockey stick” for extreme heat

- Electricity – Supply
  - Impacts efficiency of power plants
  - Fuel for power supply: Hydro, Wind, Solar
  - Severe weather can impact power transmission
    - Wind-induced power outages

Relationship of load to temperature – Cinergy 1996

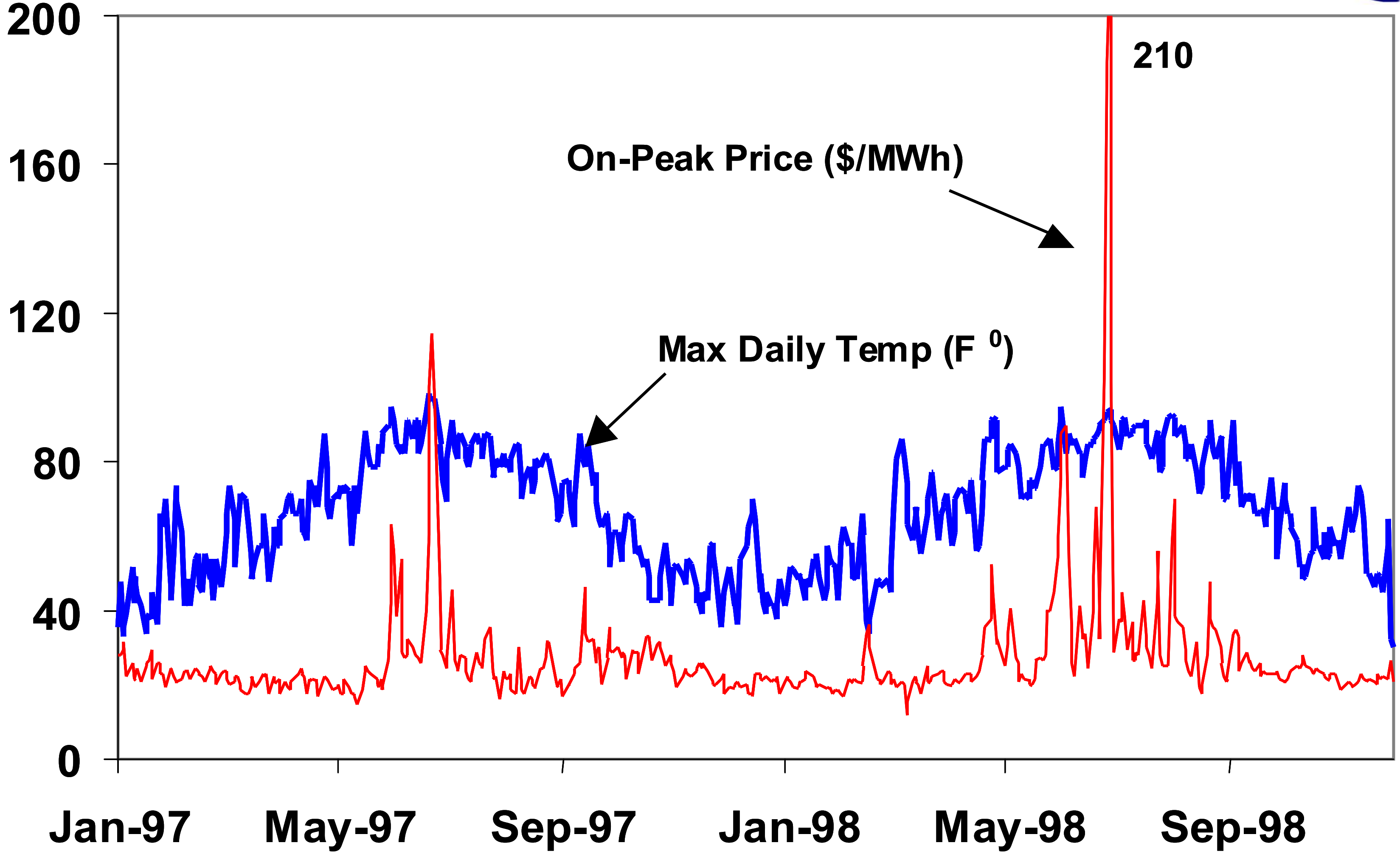


Temperatures vs. system price

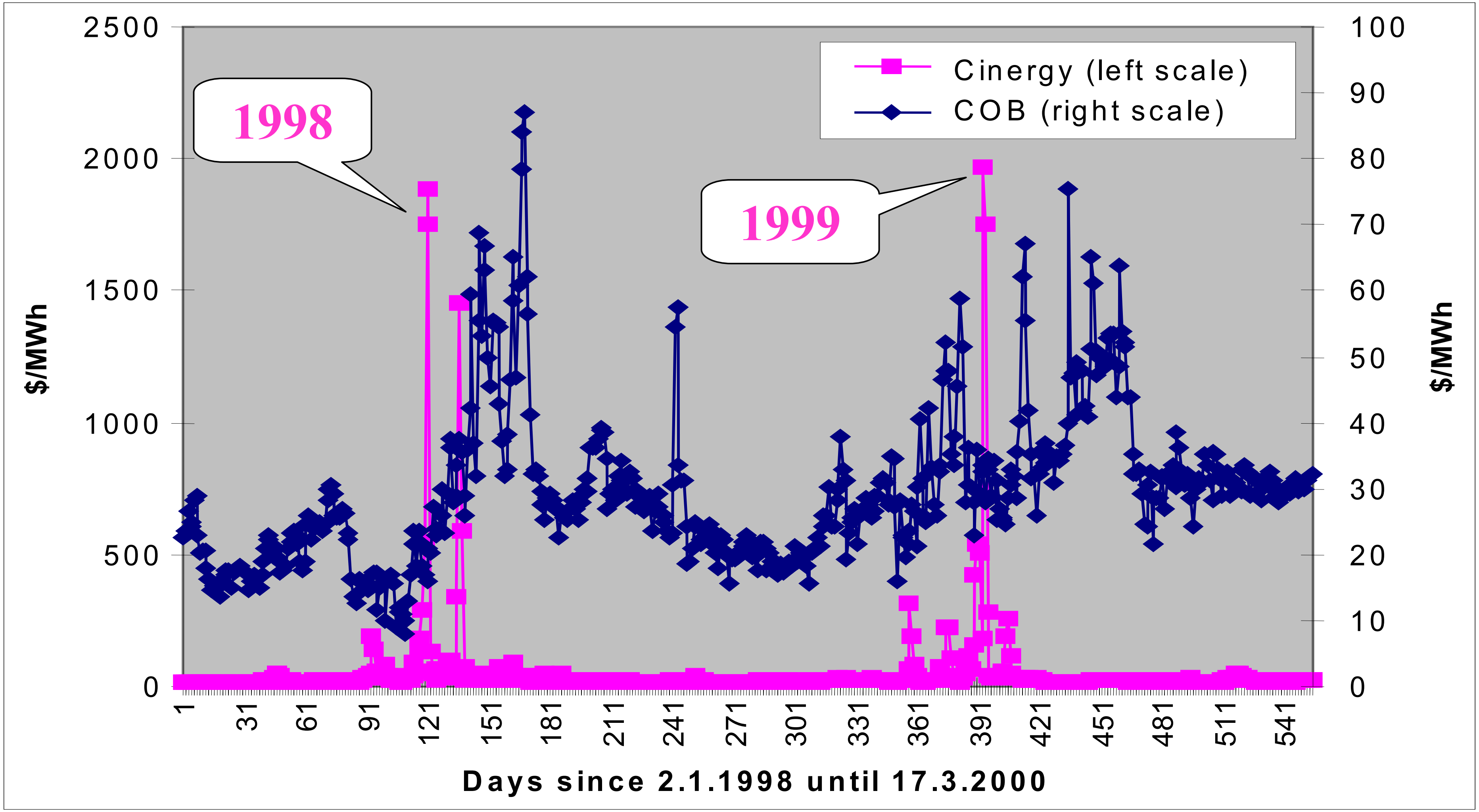


NORD POOL
THE NORDIC POWER EXCHANGE

PJM – power price vs. maximum temperature



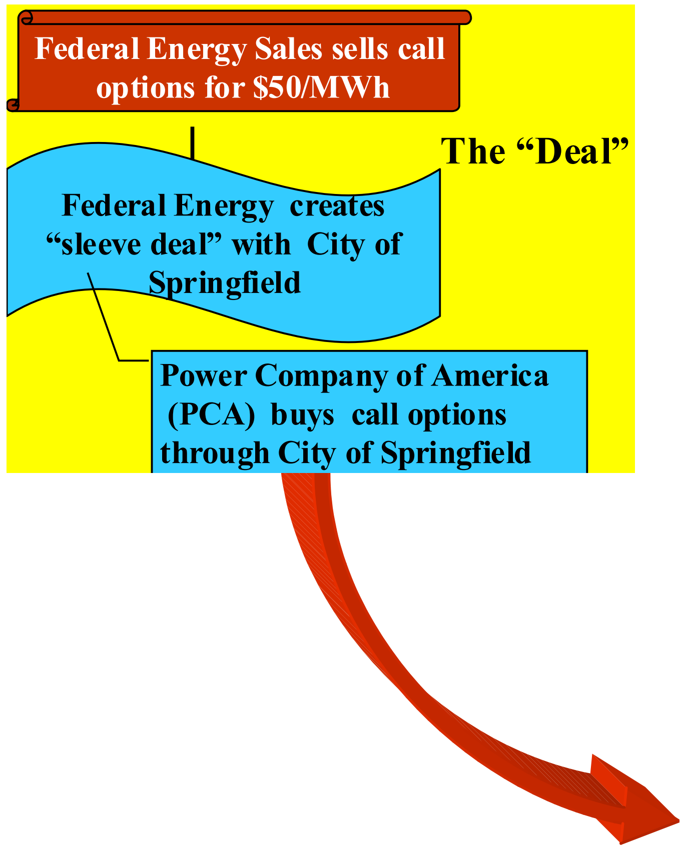
SPIKES



Cinergy (left scale)
COB (right scale)
1998
1999
$/MWh
$/MWh
2500
2000
1500
1000
500
0
100
90
80
70
60
50
40
30
20
10
0
1
31
61
91
121
151
181
211
241
271
301
331
361
391
421
451
481
511
541
Days since 2.1.1998 until 17.3.2000

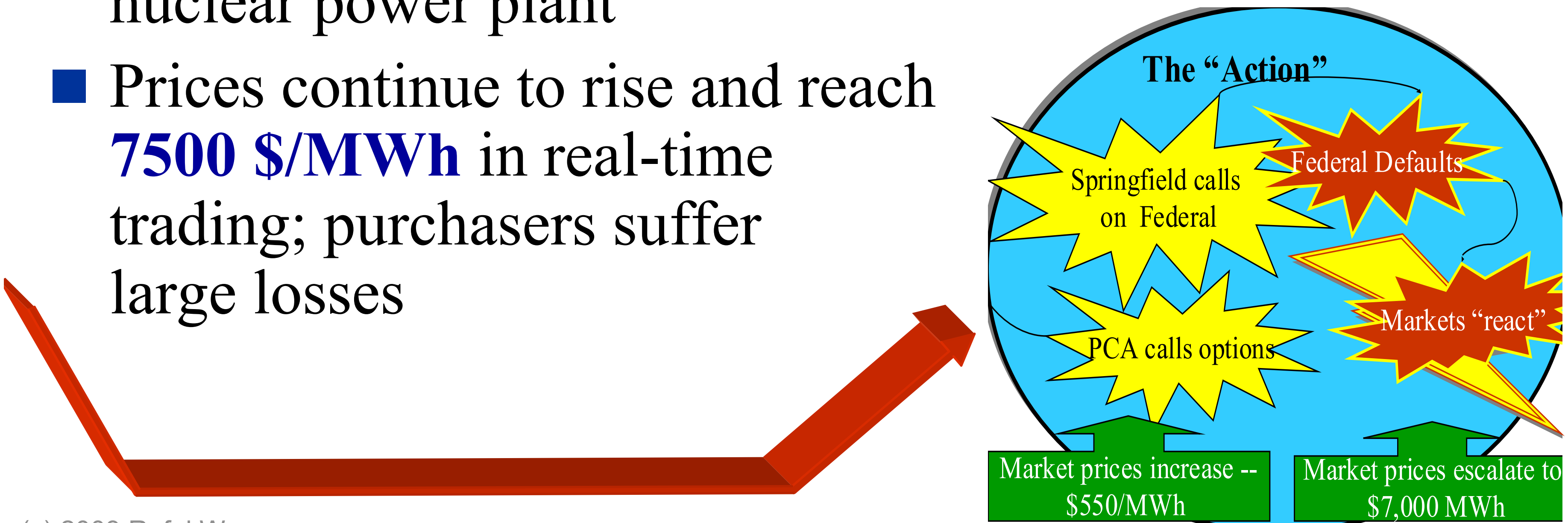
Anatomy of the 1998 Cinergy spike

- **The setup**: Federal sells call options for 50 $/MWh; “Sleeve deal” provides credit guarantees
- **End of June 1998**: an early heat wave hits the Midwest; more than 20 power plants are off-line for mainte-nance or down due to storm damage
- **June 22-24**: prices (“into Cinergy”) rise from 180 to 550 $/MWh
- Marketers anticipating price squeeze buy up power bidding prices higher



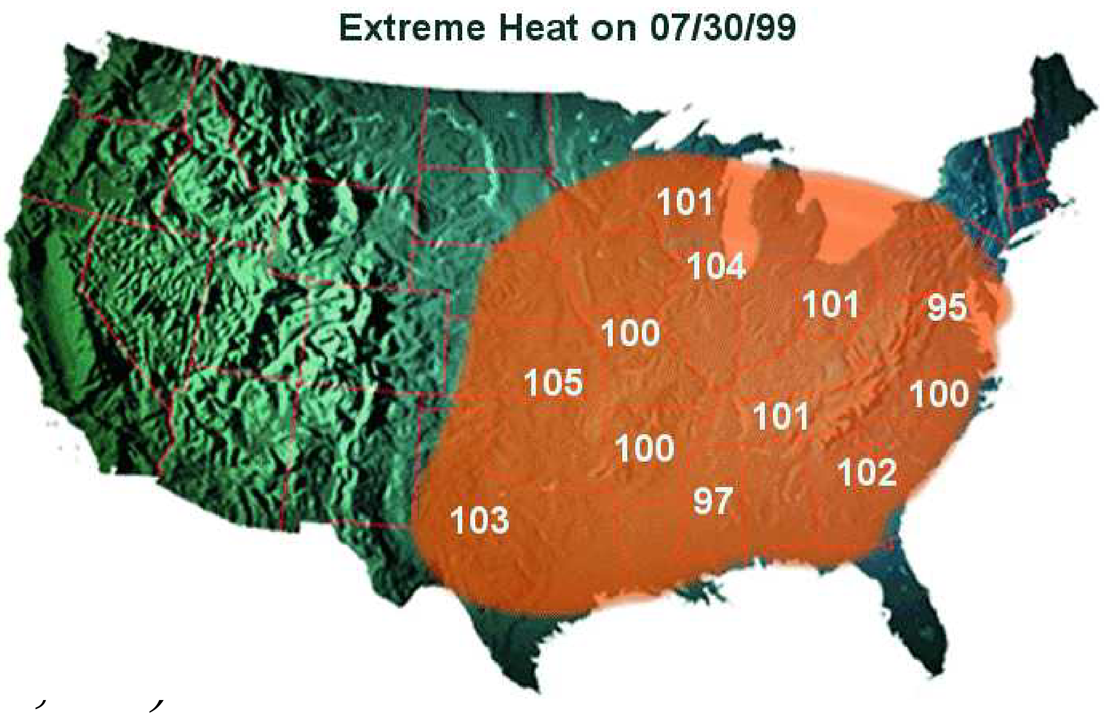
Anatomy of the 1998 Cinergy spike cont.

- Options **get called** amid high prices at Cinergy
- **Federal Energy defaults** on call options; Springfield announces that it will not perform on these options
- On the night of June 24th a tornado damages a 900 MW nuclear power plant
- Prices continue to rise and reach **7500 $/MWh** in real-time trading; purchasers suffer large losses



July 1999 Cinergy price spike

- Weather Situation
  - Last part of July – hottest temperatures in several years
  - Widespread record highs
  - Heat indices:
    115°F (Chicago)
    118°F (South Ben

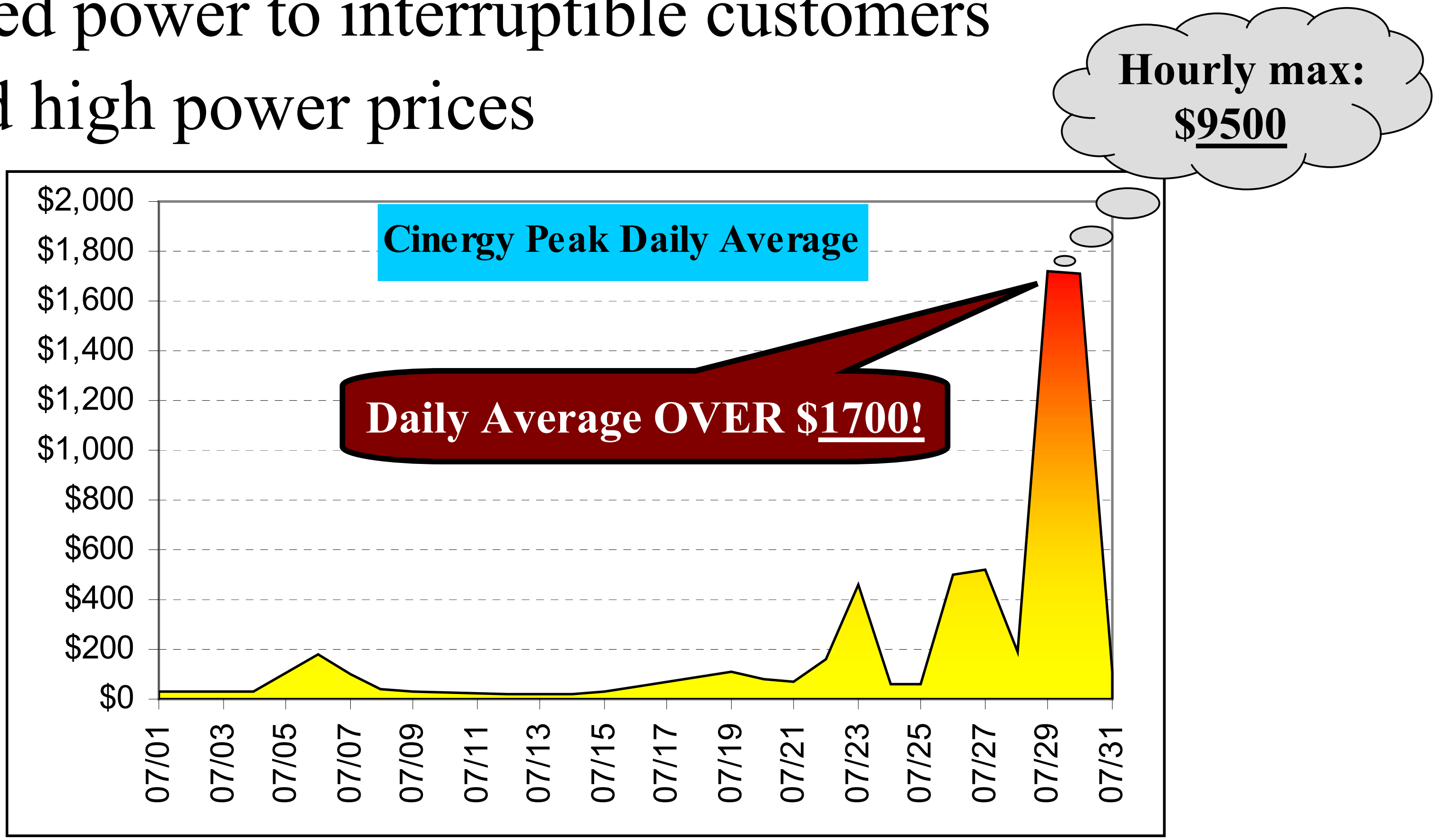


July 1999 Cinergy price spike cont.

- Energy demand
  - Record high demands in Ohio River area
- Reduced plant efficiency
  - High air/water temperatures caused generating units to run at lower efficiencies due to reduced effectiveness of cooling systems
- Other contributing energy factors
  - Strained transmission grids and flow cuts due to high energy demand
  - Market psychology

July 1999 Cinergy price spike – end results

- Power outages due to insufficient capacity
- Reduced power to interruptible customers
- Record high power prices



USA Today, 2.08.1999 r.

Conclusions ... from a three year perspective

- Power markets are different
  - than other commodity or financial markets
  - from each other
- New modeling, forecasting, pricing methods are needed
- "Blackout-free" design of power networks is necessary
- **There still is work for everyone in the room**