
Why Did the US (Mostly) Go With LMP? Benefits of Flow-Based Allocation

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*“The Role of Power Market Design or the Achievement of the 20% Renewable Target”
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Overview



1. Definition of LMP-based markets
2. Benefits of LMP
 - Categories
 - Modeling the unit commitment & international redispatch benefits
3. Why the US chose LMP
4. Continuous improvement

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1. Market Restructuring *a la* Amerique



- LMP: Settlement price = nodal λ from smart auction
 - Time varying energy + congestion + loss components
 - Calculated:
 - Ex ante (dual variables) or
 - Ex post (best supports dispatch)
 - Most transactions bilateral; λ adds transparency, liquidity
- Also (FERC Wholesale Market Platform):
 - Multi-settlement markets
 - Guarantee min load & start-up costs
 - Local market power mitigation
 - Financial transmission rights
 - Residual unit commitment commit enough to meet forecast load
 - Capacity or resource adequacy markets
 - Possibility of merchant-based transmission

To Make LMP
System Work

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2. Short-term benefits of LMP



- Within country dispatch
 - Lower congestion costs
 - Include losses in dispatch
 - Avoid Inc-dec game
 - Income transfers from consumers
- Unit commitment ****
 - Commitment based on full network
- International redispatch ****
 - Increased use of network
 - Avoid over-conservative definition of NTC
 - Avoid inefficiencies of separate allocation of T & gen
 - Increase market size, reduce local market power
- Demand response to local conditions
- Incentives for operation of network (FACTS devices)
- Increase security of network
 - Feasible day-ahead schedules

**\$170M/yr benefits
from PJM's westward
expansion**

Mansur, E., & White, M., "Market Organization and Market Efficiency in Electricity Markets," Yale School of Management Working Paper, June 2009.

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Long-run benefits from LMP



- Incent appropriate siting of gen, load
- Information for T investment
- Reduced need for T investment

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Modelling the Unit Commitment & International Redispatch Benefits of LMP

Harry van der Weijde & Ben Hobbs, EPRG

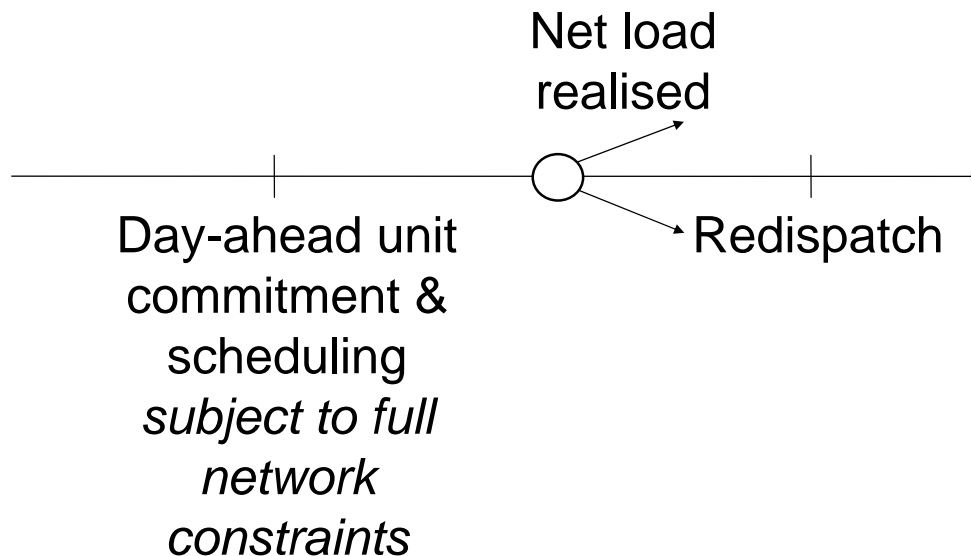


- 3 models of commitment & dispatch costs
 - **LMP**
 - commit s.t. full network (best!)
 - **NTC-IRD**
 - commit s.t. NTC, international redispatch
 - **NTC-NoIRD**
 - commit s.t. NTC, adhere to day-ahead intl MW
 - Quantified for two NTC cases:
 - Optimal NTC (chosen to MIN C)
 - Arbitrary (fixed) NTC
 - Sensitivity to generator sizes, load characteristics
-

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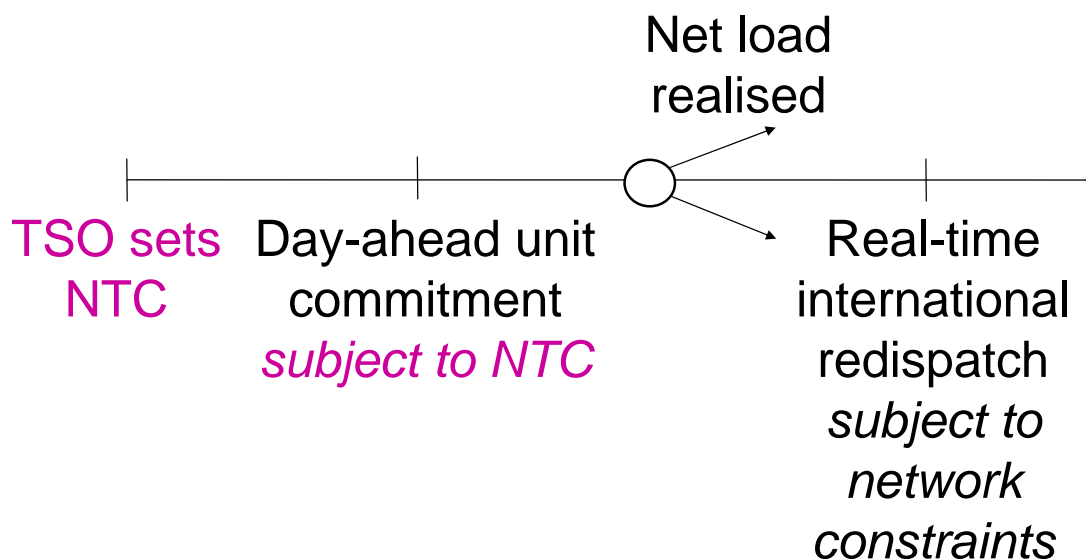
Model LMP



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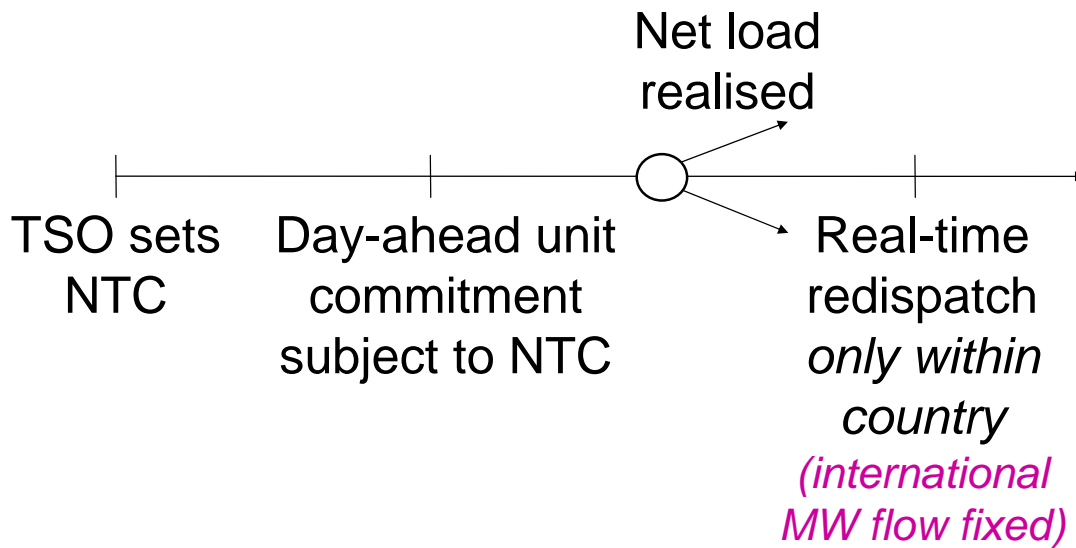
Model NTC-IRD



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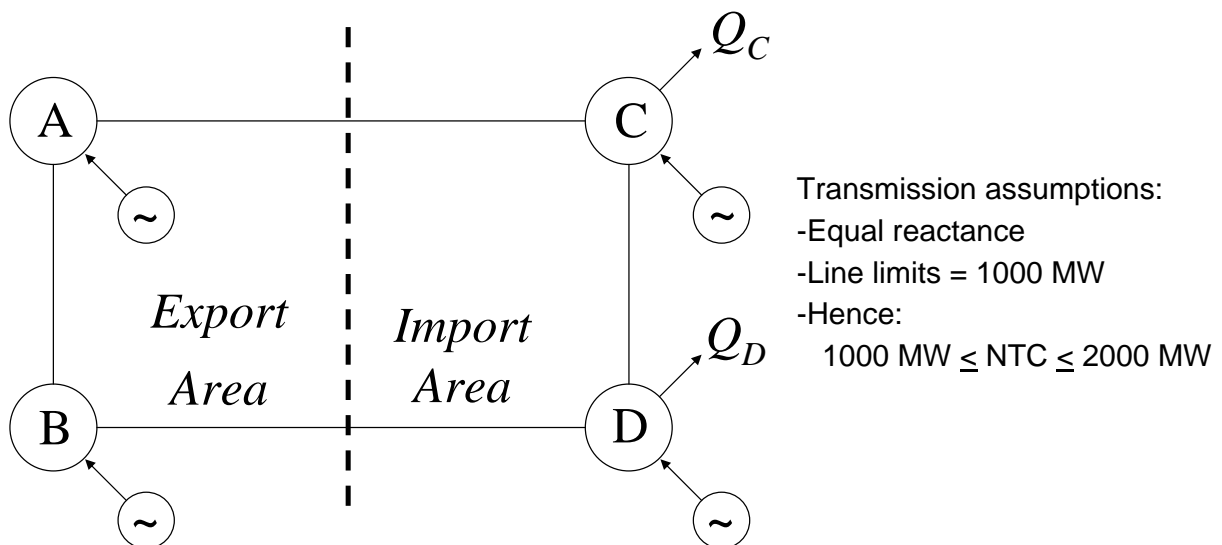
Model NTC-NoIRD



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Network

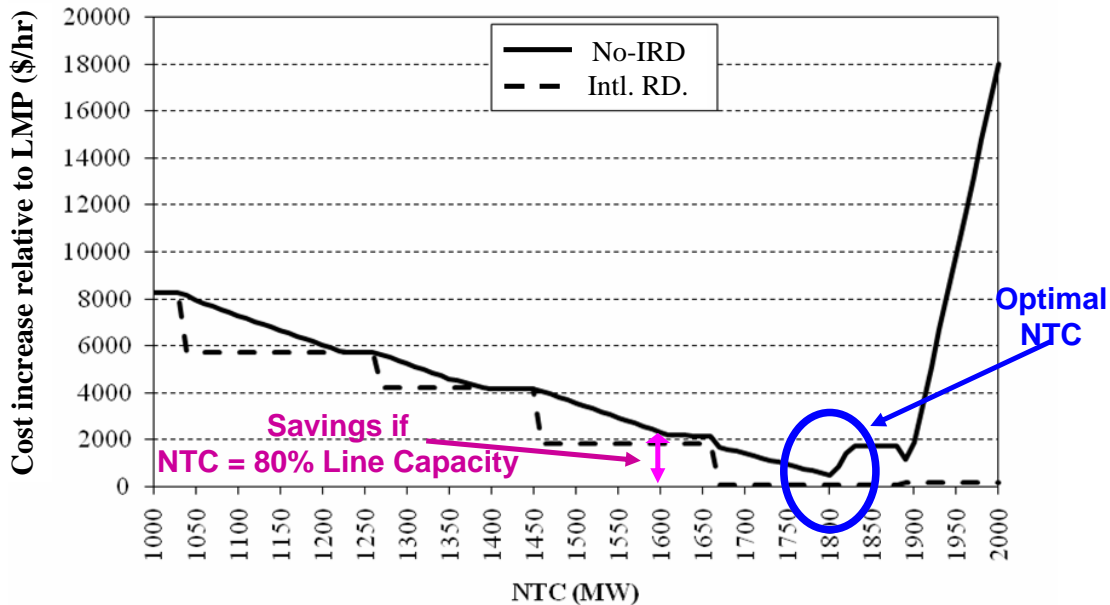


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Results Base Case

Note: LMP cost = \$102,000/hr












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Conclusions



- Unit commitment & redispatch benefits of LMP
 - ~ 0.1-5% of production costs
- But depends on exact load & gen parameters!
 - If optimize NTC:
 - 0-1.7% with intl real-time redispatch
 - 0-2.7% without    
 - If set NTC = 80% of line capacity:
 - 0-5.3% with intl real-time redispatch
 - 0-9.5% without    
- Cf. other studies
 - 0.1% Unit commitment benefits in EU (R. Barth et al., Load-Flow Based Market Coupling with Large Scale Wind Power in Europe. 8th Workshop on Large-Scale Integration of Wind Power in Power Systems, 2009)
 - 0.38 /MWh Intl. redispatch benefits in F-Be-NL-G example (Oggioni & Smeers, Degrees of Coordination in Market Coupling and Counter-Trading, UCL, 2009)

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Work in Progress?

Model Comparison: Renewables Network Integration, Benefits of Flow-Based vs. NTC-Based Allocation



DIW / CPI Berlin

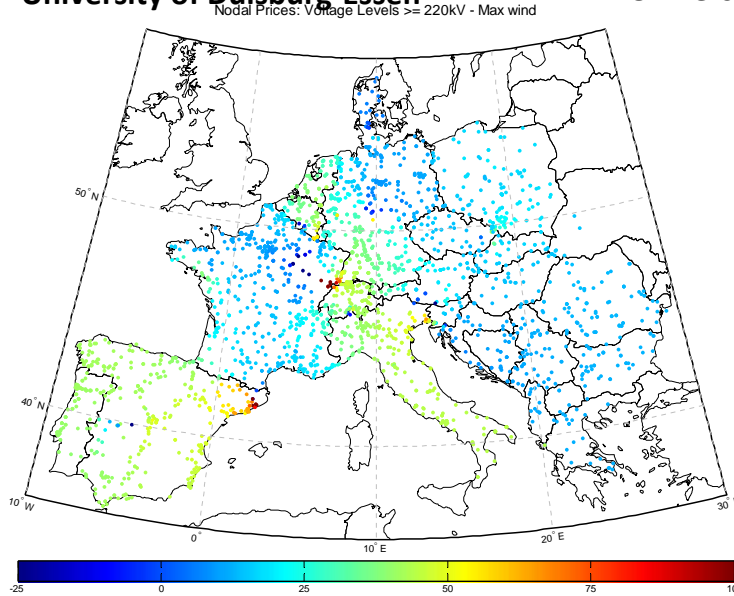
Ecofys

University of Duisburg-Essen

TU Dresden

Universidad Pontificia Comillas

University of Durham



Maxwind

Ecofys

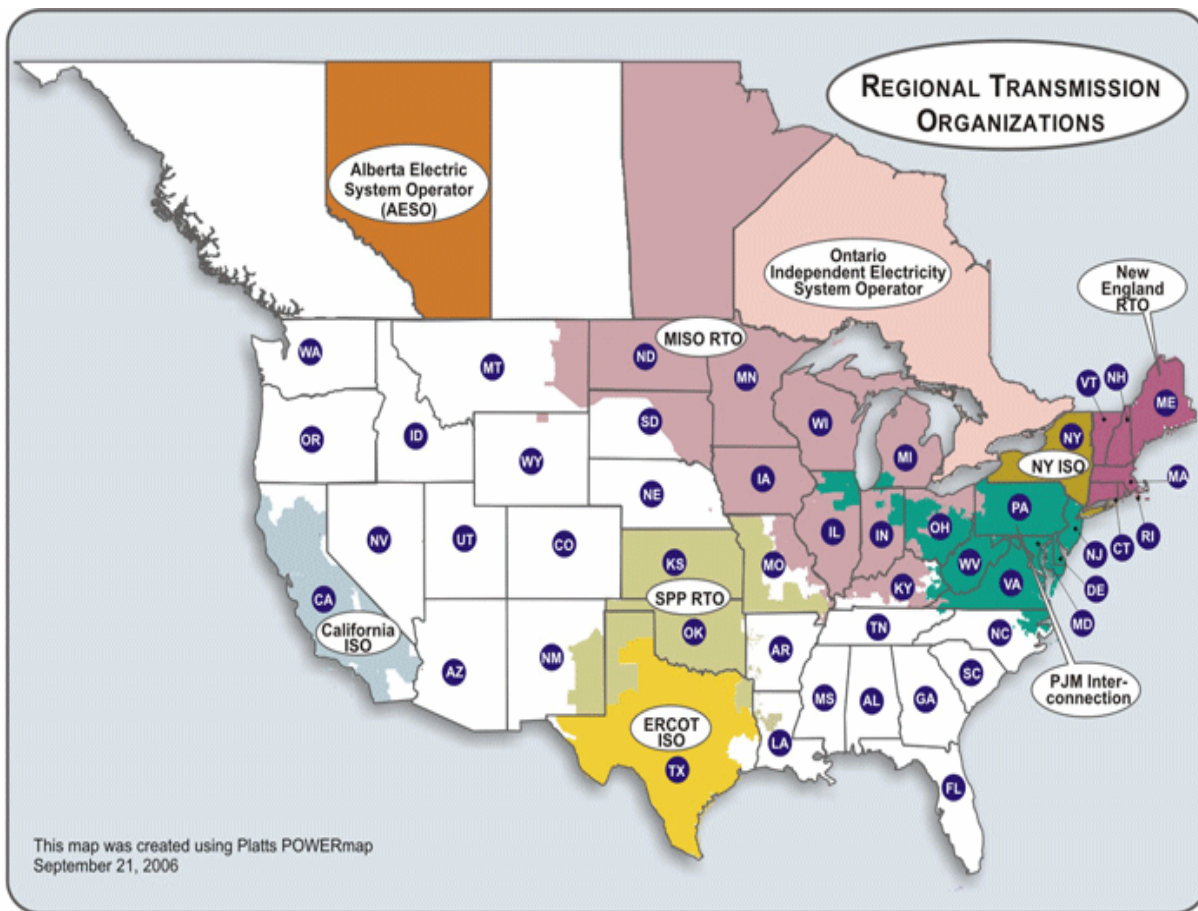
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Answer:
**❓Zonal❓ Pricing Failed:
 Learning the Hard Way**



- **California 2004**
- **PJM 1997**
- **New England 1998**

Better to recognize spatial & intemporal constraints by pricing them than to make believe they don't exist

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The **DEC** Game in Zonal Markets



- **Clear zonal market day ahead (DA):**
 - One supply curve from all gen bids
 - Clear against zonal load
 - Accepted bids paid DA price
- **Intrazonal congestion arises in real-time & must be eliminated**
 - **INC** needed gen that wasn't taken DA
 - Pay them $>$ DA price
 - **DEC** unneeded gen that can't be used
 - Allow generator to pay back $<$ DA price

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Problems arising from **DEC** Games



1: Congestion worsens

- Gen you want won't enter DA
- But gen you don't want will!
- E.g., PJM 1997

2: DEC game is a money machine

- Gen pocket generators bid cheaply, knowing they can buy back at lower price
 - E.g., $P_{DA} = \$70$, $P_{DEC} = \$30$
 - Make \$40 for doing nothing
- E.g., California 2004

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Problems arising from **DEC** Games



3: Short Run Inefficiencies

- If **DEC**ed gen started up & then shut down
- If **INC**ed gen needed at short notice

4: Long run siting inefficiencies

- Complex rules required to correct perverse incentives
- E.g., New England 1998, UK late 1990s



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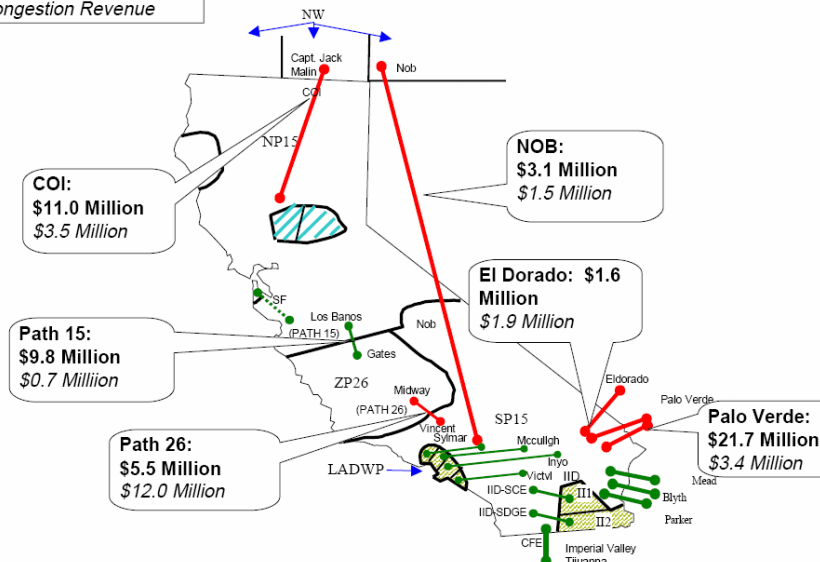
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Example 1: Cost of DEC Game in California



- Three zones in 1995 market design
- Cost of **Interzonal-Congestion Management**:
 - E.g., \$56M (2004)

2004 Congestion Revenue
2003 Congestion Revenue

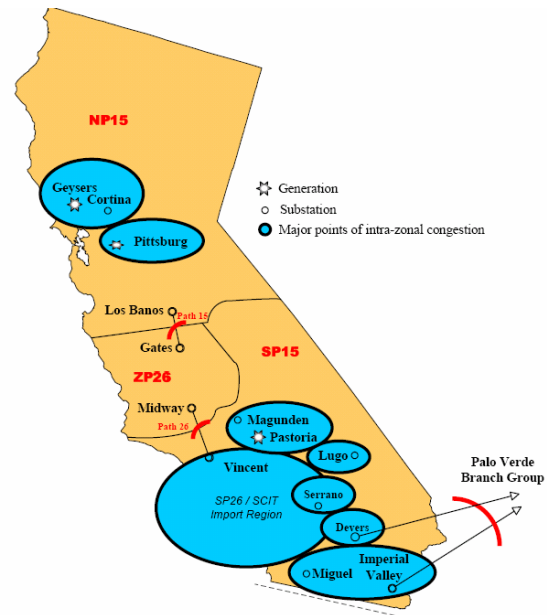


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Intrazonal Congestion in California (Real-Time Only)



- **\$426M (2004)**
- **Mostly transmission in load pockets**
- **Managed by:**
 - **Dispatching [?]Reliability Must Run[?] and [?]minimum load[?] units**
 - **INC[?] and DEC[?]**
 - [?] Mean INC price = \$67.33/MWh
 - [?] Mean DEC price = \$39.20/MWh



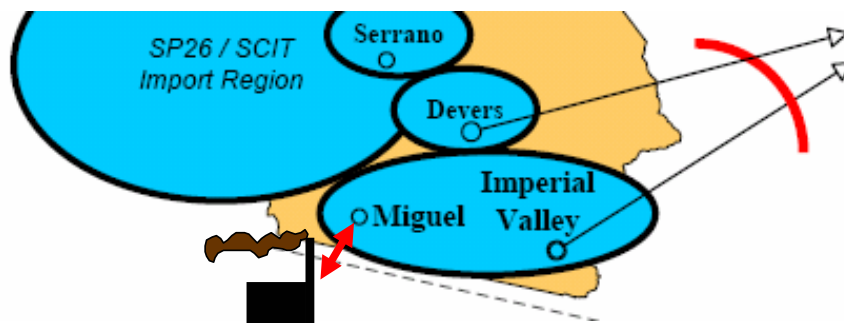
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Miguel Substation Congestion



- **1070 MW new gen in Mexico**
 - In SoCal zone
- **Miguel substation congestion limits imports to SoCal**
 - So INC San Diego units
 - DEC Mexican or Palo Verde imports
- **Mexican generation submit very low DEC bids**
 - In anticipation, CAISO Amendment 50 (March 2003) mitigated DEC bids
- **Nonetheless, until Miguel upgraded (2005), congestion management costs ~ \$3-\$4M/month even when mitigated**
 - Value to Mex gen: ~\$5/MW/hr



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Example 2: PJM Zonal Collapse



- **New 1997 PJM market: zonal DA prices**
 - Congestion to be cleared by RT **INCA** and **DECA**
- **Generators had two options:**
 - Bid into zonal market
 - Bilaterals (sign contract with load, submit fixed schedule)
 - ⇒ **HUGE number of infeasible bilaterals with cheap western gen**
 - PJM emergency restrictions June 1997
- **PJM requested FERC permission for LMP, operational in April 1998**
(Source: W. Hogan, *Restructuring the Electricity Market: Institutions for Network Systems*, April 1999)



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Example 3: Perverse Siting Incentives in New England



- **Before restructuring, 1 zonal price**
- **After market opened in late 1990s, ~30 GW new plant announced (doubled capacity)**
 - To correct perverse siting incentives, NEPOOL proposed complex rules
 - extensive studies of system impacts
 - expensive investments in the transmission system.
 - Rules delayed & increased entry costs, protecting existing gen from competition
- **1998, FERC struck down rules as discriminatory and anticompetitive responses to defective congestion management**
 - ISO-NE submitted a LMP proposal in 1999 which was accepted

(See W. Hogan, *ibid.*)

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4. Implementing LMP: Ongoing Improvement



- **Basic principles of *Wholesale Market Platform* work well**
 - *Price all constraints*
 - *Facilitate trade between markets*
 - *Forward contracting*
- **Stakeholders want it to work even better**
 - *24 hrs → several days*
 - *Better security: zonal operating reserves, contingencies*
 - *AC load flow*
 - *Deal with seams barriers between LMP markets*
 - *More temporal variation to reward flexible investment*
 - *Scarcity pricing and *resource adequacy* to incent investment at right time & place*
 - *Minimize distortion from exclusion of constraints, operator decisions*

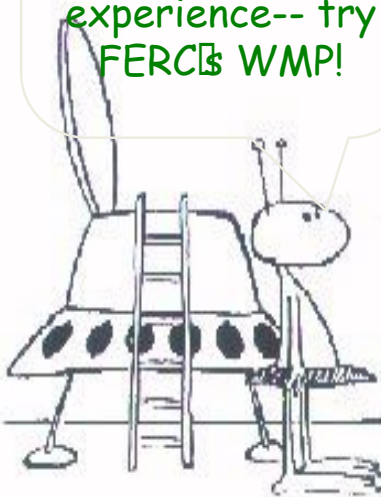
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Conclusion

You don't always get it right the first time.

Now you have experience-- try FERC & WMP!



NO, WE DIDN'T NIKE OURSELVES BACK INTO THE STONE-AGE. WE DEREGULATED OUR ELECTRIC UTILITIES...



Thanks to Dick O'Neill, FERC

Readings on LMP



General:

- R. Baldick, U. Helman, B.F. Hobbs, and R.P. O'Neill, "Design of Efficient Generation Markets," *Proceedings of the IEEE*, 93(11), Nov. 2005, 1998-2012.
- R.P. O'Neill, U. Helman, and B.F. Hobbs, "The Design of U.S. Wholesale Energy and Ancillary Service Auction markets: Theory and Practice," Ch. 5, in F.P. Sioshansi, *Competitive Electricity Markets: Design, Implementation, Performance*, Elsevier, 2008.
- R.P. O'Neill, U. Helman, B.F. Hobbs, and R. Baldick, "Independent system operators in the United States: History, lessons learned, and prospects," Ch. 14, in F. Sioshansi and W. Pfaffenberger, *Electricity Market Reform: An International Perspective*, Elsevier, 2006, 479-528.

Presentation References:

- R. Barth et al., Load-Flow Based Market Coupling with Large Scale Wind Power in Europe. 8th Workshop on Large-Scale Integration of Wind Power in Power Systems, Duisberg-Essen University, 2009
- W. Hogan, Restructuring the Electricity Market: Institutions for Network Systems, April 1999 (available Harvard Electricity Policy Group HEPG Website)
- G. Oggioni & Y. Smeers, Degrees of Coordination in Market Coupling and Counter-Trading, Universite' Catholique Louvain-la-Neuve, 2009

ISO LMP Training Materials

CAISO MRTU training

- Locational Marginal Pricing (LMP) 101 Course Overview of Locational Marginal Pricing
- <http://www.caiso.com/1824/18249c7b59690.html>
- <http://www.caiso.com/20a6/20a690af67c80.html> slides only
- New England
- http://www.iso-ne.com/nwssis/grid_mkts/how_mkts_wrk/lmp/index.html
- PJM Training Curriculum
- http://www.pjm.com/sitecore/content/Globals/Training/Courses/ol-lmp-101.aspx?sc_lang=en
- <http://www.pjm.com/~media/training/core-curriculum/ip-lmp-101/lmp-101-training.ashx>
- <http://www.pjm.com/~media/training/core-curriculum/ip-gen-101/20050713-gen-101-lmp-overview.ashx>
- https://admin.acrobat.com/_a16103949/p20016248/ with audio accompaniment

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