Market Design for Future Systems With a High Share of Renewable Energy: Fitness or Witless for Purpose?

Benjamin F. Hobbs, bhobbs@jhu.edu

Schad Professor of Environmental Management, The Johns Hopkins University
Department of Environmental Health & Engineering
Leadership Council, JHU Ralph O'Connor Sustainable Energy Institute

Chair, California ISO Market Surveillance Committee

Co-Organizer,Columbia-JHU Future Power Markets Forum (powermarkets.org)

ESIG, Feb. 23, 2023

Thanks to my GMLC collaborators, especially Erik Ela & Audun Botterud; my CAISO colleagues; my students Qingyu Xu, Shen Wang, & Yinong Sun, and to USDOE, NSF for support. Usual caveat applies.

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

Question:

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

Is the "standard" power market design "fit for purpose" today?...

…Given:

- ***Rapid technology change?***
  From dispatchable fossil resources to….
  - **Zero (or less!) cost variable renewable energy (VRE)**
  - **Battery storage linking markets over time**
  - **Demand response, distributed resources**
- ***And ambitious decarbonization goals (IPCC 2022)?***

Future Power Markets Forum
powermarkets.org

A PROJECT OF

JOHNS HOPKINS RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

COLUMBIA | SIPA Center on Global Energy Policy

JOHNS HOPKINS RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

Which market design issues are crucial to discuss for the transition?

62 members reviewed the topics of the first 25 forums, and identified up to three that are worth updating or need new perspectives

- 19: RA; capacity/energy adequacy; adequacy criteria
- 11: Transmission policy & planning
- 8: Long-term procurement
- 7: DR and DERs
- 6: A/S & energy spot markets

JOHNS HOPKINS RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

Outline

I. Intro to power markets
II. Is the basic LMP framework still fit for purpose?
III. …And what about capacity markets?
IV. Some alternatives for future designs
V. Need sound transmission & carbon policy

I. Introduction: Markets for Power

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

- **Why? Inefficiencies in:**
  - investment
  - operations
  - pricing
- **Some Key Developments**
  - 1978 PURPA (US), Margaret Thatcher (UK)
  - Fred Schweppe
  - →Over half of US unbundled/deregulated
    - Then California Crisis!
    - Since then, incremental market reforms

Power systems '2000': hierarchical control strategies

Multilevel controls and home minis will enable utilities to buy and sell power at 'real time' rates determined by supply and demand

Thanks to Ignacio Perez-Arriaga

How Principles Have Been Applied in US Markets: "Standard Market Design+" (SMD+)

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

- **Short-run spot markets:**
  - Supply offers reflect internal costs & constraints
  - Co-optimize energy, reserves, & transmission use
  - 2+ settlements
  - Energy settled at locational marginal prices (LMPs)
- **Long-run investment:**
  - Capacity markets
  - Renewable portfolio standards/tax credits
  - Regional transmission planning

Schweppe's Vision

- **Theoretical efficiency results (given just a few assumptions…)** (Bohn et al., 1986)**:**

1. Solution to OPF = Solution to competitive market

<u>Efficient</u> dispatch…

…and long run investment!

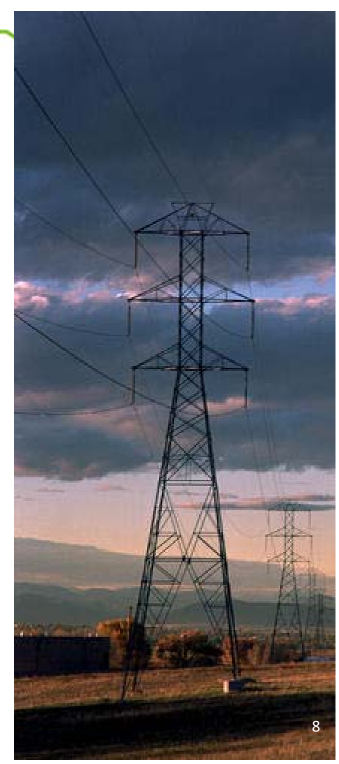
2. Thus: LMPs "support" the optimal solution

Pay LMPs energy & reserves ….

….*Then* the <u>system-optimal</u> schedule for each resource also <u>maximizes their profit</u>

… And revenue is adequate to cover capital costs

Assumptions



- **Market power <u>mitigated</u>**
- **<u>No distortions</u> in prices (from price caps, price averaging over time, …)**
- **<u>Perfect</u> information**
- **<u>Convex</u> costs & constraint sets**
- **Solutions <u>computable</u>**

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

Outline

I. Intro to power markets
II. Is the basic LMP framework still fit for purpose?
III. …And what about capacity markets?
IV. Some alternatives for future designs
V. Need sound transmission & carbon policy

II. Today's <u>LMP-Based Spot Market</u> Design: *Fit for Purpose?*

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

http://damanino.com/5-signs-of-a-poorly-made-suit/

- Adequately incent **decarbonization**?
- Reward **flexibility** to back up VREs?
  - Now: Volatility suppressed by long settlement intervals & lack of uncertainty in market models (Lund et al. 2015)
- Engage **demand side**; consistent incentives for DER v. grid-scale **siting?**
- Right **horizons** for storage?
  - Now: Truncated horizons

II.1 Where’s the active demand-side?

- **US Power Markets still (mainly) half a market**
  - “Dumb meters/grid” (average cost pricing, uninformed consumers)
    - Despite $5B in smart meter investment
  - Just 3% of US residential customers on time-varying rates (Hledik et al. 2017). E.g., California:
    - Retail TOU rates are, e.g., 17-30 $/MWh
    - Wholesale prices can be -300 to +2000 (or more) $/MWh
  - High volumetric rates skew solar investment to high-cost residential installations

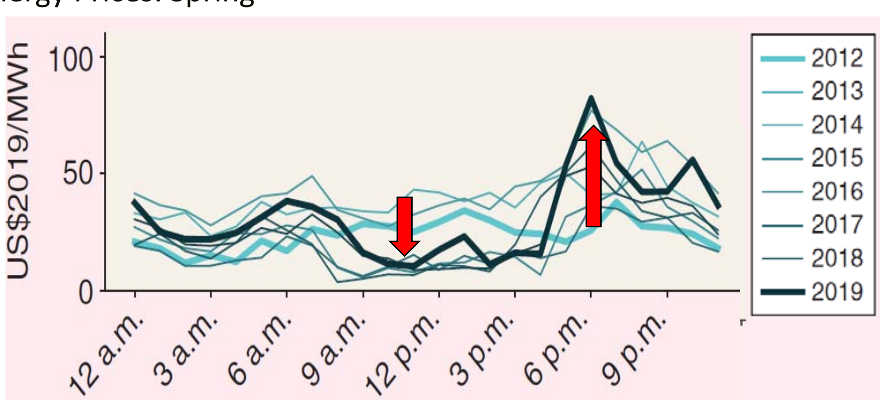
smartmeterresources.com

II.2 How will High VRE Penetration affect LMPs?

(Ela et al. 2021; Mills et al. 2020; OECD, Nuclear Energy Agency 2019)

- ***Will spot prices be “bipolar”?***

CAISO Energy Prices: Spring



- ***Will instability discourage investment?***
- ***Will back-up flexible power sources revenue-inadequate?***

How will High VRE Penetration affect LMPs?

➢ ***The Reality:*** **price distributions will change by 2040-2050, but prices will often be at intermediate levels. Why?**

- ***Backup power running costs:*** **Fuel costs (bioenergy, CCS-fossil) will often set prices (Sepulveda et al., 2020)**
- ***Sectoral coupling ("Power to X"):*** **methanation, Fischer-Tropsch, H_2 could drop long-run VRE curtailment from ~33% to ~5% (Evolved Energy, 2021)**
- ***Scarcity:***
  - **"Operating reserve demand curves" goose prices gradually when capacity short (Frew et al., 2021; Mehrtani et al. 2022)**
  - **Realizing Schweppe's dream: demand response *at all times* – EVs, building thermal storage etc. (Cruz et al. 2018)**
- ***Storage:***
  - **Correct storage degradation models will smooth price variations due to cost of deep drawdowns** (Padmanabhanet al. 2019, Zheng et al. 2022)
  - **Opportunity costs rise smoothly, accounting for uncertain scarcity (E.g., Ontario Hydro; Ela et al. 2021)**

VREs & storage don't change Schweppe's basic conclusion: In theory, LMPs can support optimal operations & investment

Extending classic analyses (Bohn et al. 1986, Stoft 2002), Korpas & Botterud (2020) consider optimal investment & dispatch of VREs & storage, as well as thermal capacity, given varying load:

- **In markets with scarcity pricing/no price caps: LMPs enable *all* capacity, including VREs & storage, to:**
  - **recover all costs**
  - **be optimally sized & operated**
- **Other show that social goals can be efficiently accommodated, if policy constraints priced (Baldick, Bushnell, Hobbs, Wolak, 2011)**

⇒"Think twice before embarking on complete re-design of electricity markets"

Outline

I. Intro to power markets
II. Is the basic LMP framework still fit for purpose?
III. …And what about capacity markets?
IV. Some alternatives for future designs
V. Need sound transmission & carbon policy

III. Today's *Capacity* Market-Based Designs: *Fit for Purpose?*

NEW OR ASSUMED AWAY CHALLENGES:

1. **New technologies:** How to handle correlated outputs of variable renewables / storage?

2. **Extreme events/profound uncertainty?**

3. **Missing demand-side, and retail/wholesale divide:** How to engage demand side & avoid skewed investment?

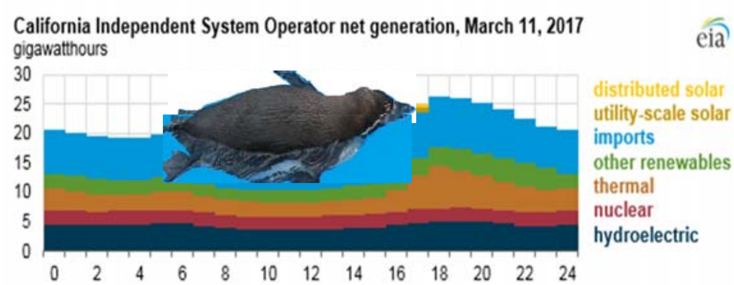
http://damanino.com/5-signs-of-a-poorly-made-suit/

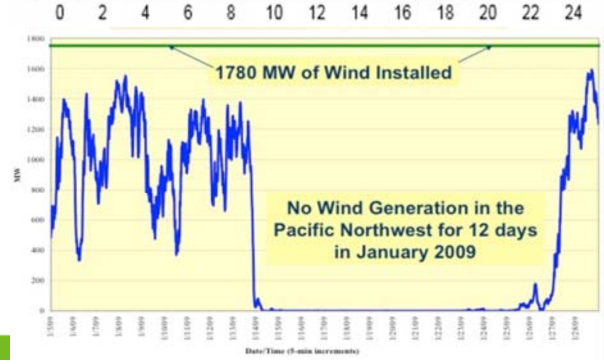
Making <u>Tomorrow's</u> Capacity Markets *Fit for Purpose*

1. **New technologies:** How to handle correlated loads and outputs of variable renewables / storage
   - *Approach:* rigorous capacity credits ("effective load carrying capability"), with strengthened scarcity pricing in spot markets
2. **Extreme events/profound uncertainty?**
   - NERC/Federal/State Regulatory standards, with nondistortionary cost recovery
3. **Missing demand-side; retail/wholesale divide:**
   - *Approaches:* Include dynamic marginal component in retail rates; careful evaluation of demand-based capacity programs

III.1 New and Highly Correlated Resources

- **Complications from renewable correlations**
  - CAISO Duck (?) curve
  - Long tails of distribution (*dunkelflaute)*
  - Other issues as renewables grow:
    - Timing of system stress shifts & is less predictable
    - Marginal contribution of renewable capacity declines





Equivalent Firm Capacity Method (EFC)
(S. Wang, B. Hobbs, et al. *IEEE TPWRS*, 2022)

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

THEORY: For a system with correlated variable renewables, storage, and dispatchable gen:

- **IF RA market pays accurate marginal capacity credit for all resources, and the reserve margin is adjusted appropriately to reflect the value of lost load, ….**
- **THEN a capacity market can duplicate the efficiency of the ideal Schweppe/LMP spot market solution**

PROCEDURE

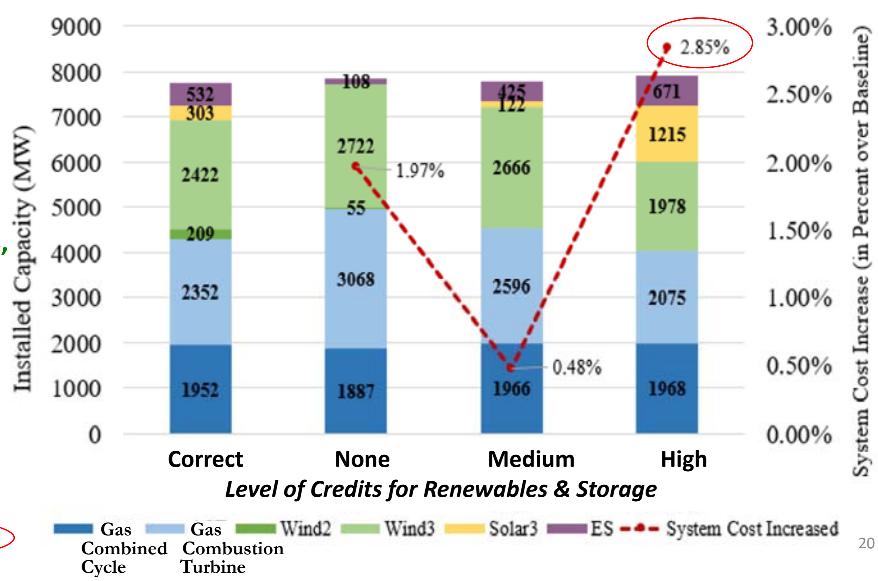
- **Step 1: Define the target unserved energy and a starting point CAP^o (close likely optimum)**
- **Step 2: Use finite differences in a dispatch model to evaluate $\partial UE/\partial cap_i$ and the resulting $EFC_i = (\partial UE/\partial cap_i)/(\partial UE/\partial FC)$, and the implied target equivalent capacity $\Sigma_i\, cap_i^o * EFC_i$**
- **Step 3: Implement resulting capacity credit market→*Prices support optimal investment***
- **Step 4: iterate if necessary**

What if we get capacity credits wrong?

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

- **Distortions in Texas-like system with different credits under 40% renewable penetration (portfolio standard), $1K/MWh price cap, and $10K/MWh VOLL:**
  - **Correct (Wind2 22%, Wind3 1.5%, Solar3 48%, Storage 82%)**
  - **None (No capacity constraint; energy- only market)**
  - **Medium (Wind 15%, Solar 40%, Storage 60%)**
  - **High (Wind 25%, Solar 100%, Storage 100%)**

$360M/y loss in worst case



II.2 Common mode failures & extreme events

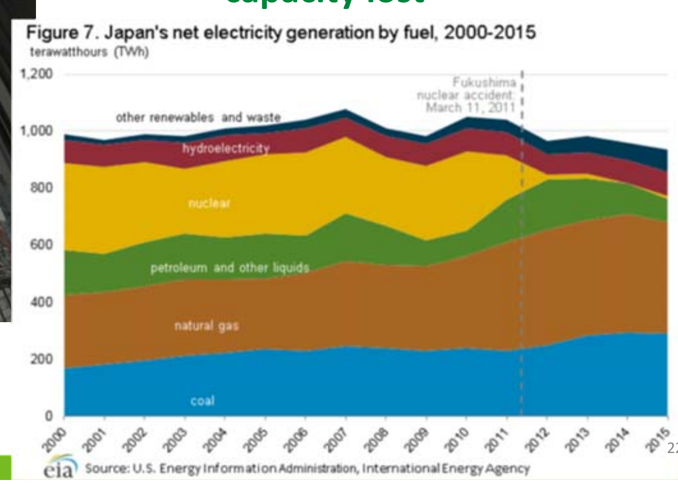
… In theory can be included in capacity markets if with known probabilities and a credible model… but many involve profound uncertainty

→ Energy shortfalls due to inadequate fuel would occur with almost every fuel-mix scenario in winter 2024/2025, requiring frequent use of **emergency actions** to keep power flowing and protect the grid. Emergency actions that would be visible to the public range from requests for energy conservation to load shedding (rolling blackouts affecting blocks of customers).

Extreme events/profound uncertainties

www.carbonbrief.org/analysis-the-legacy-of-the-fukushima-nuclear-disaster

Fukushima: 17% of Japan's capacity lost



Correlations Among Different Stressors

"When sorrows come, they come not single spies. But in battalions."

King Claudius, *Hamlet* (Thx to Roger Cooke et al.)

- **Ten Plagues of Egypt: *California 2000-01***
  - **Fuel (gas compressor station outage)**
  - **Hydro shortage**
  - **NO_x allowance shortages**
  - **Kelp**
- **Interdependent infrastructure: Texas 2021: Gas-electricity interdependency, compounded by inability to efficiently ration**
- ***In theory* model-able**

www.powermag.com/prepare-your-gas-plant-for-cold-weather-operations/

Role of Markets for Managing Extreme Risks

For extreme events:

- Probability estimates are unreliable
- Insurance is unlikely to be available or very expensive

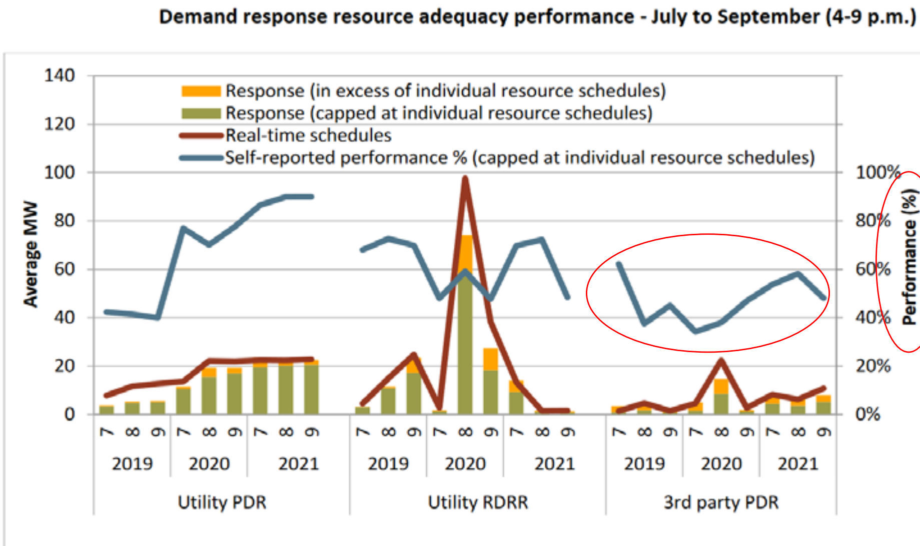
...three particular phenomena of climate related risks that will require a change in our thinking about risk management: global micro-correlations, fat tails, and tail dependence. (Their) consideration …will be particularly important for natural disaster insurance, as they call into question traditional methods of securitization and diversification (Kousky & Cooke, RFF-DP-09-03-REV.pdf, 2009)

Public good of network reliability → central planning, FERC/NERC rules, …

(Quasi) market roles:

- Bidding to provide equipment, services
- Performance-based ratemaking for infrastructure owners

III.3 Uncertain and so-far disappointing performance of demand-response programs in capacity markets



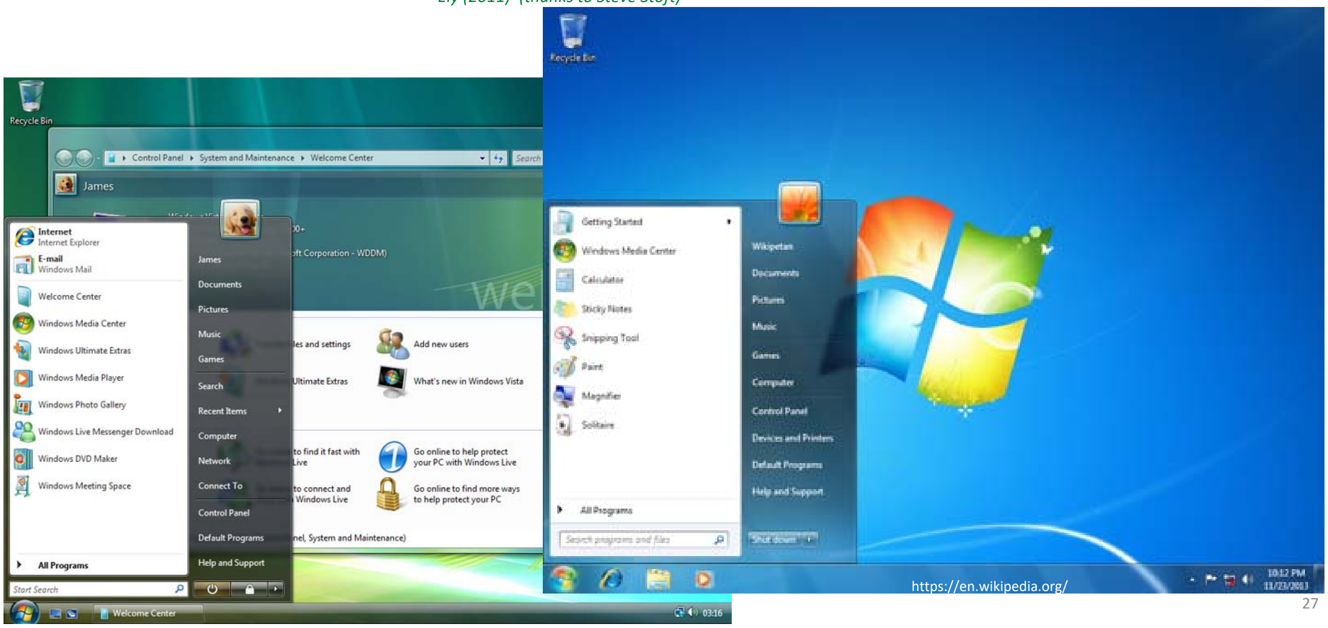
Source: CAISO Dept. Market Monitoring Annual Report for 2021

Outline

I. Intro to power markets
II. Is the basic LMP framework still fit for purpose?
III. …And what about capacity markets?
IV. Some alternatives for future designs
V. Need sound transmission & carbon policy

III. When ought you kludge
… and when start from scratch?

Ely (2011) (thanks to Steve Stoft)



Some Possible Long-Run Market Design Strategies

1. ***Incrementalism*** **(ISOs)**
   - **Easiest**
   - **But danger of kludges**

2. *"A la EU"*: Increase # settlements & time horizon, but omit details on internal resource constraints (e.g., Matt White ISO-NE)

- **Better reflects updated forecasts**
- **Gives up on verifying costs, nixing US-style market power mitigation**

3. *Capacity-based retail contracts* (ZOMEHOME; Lo et al. 2019)

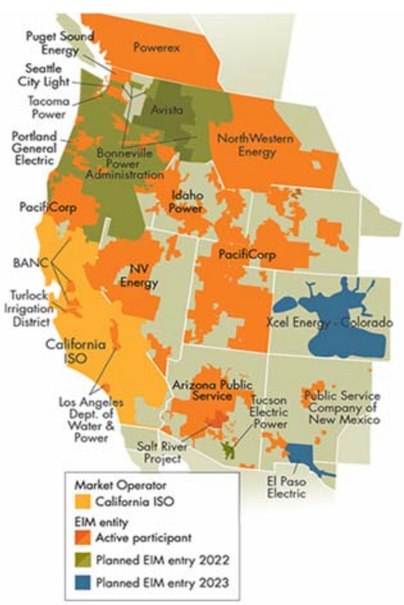
- **Consumers like; fits zero short-run cost world**
- **But spot prices actually will be significant**

Alternative Long-Run Design Strategies

4. ***Investment auctions*: Decades-ahead resource & transmission auctions, with clean energy constraint** **(Ela et al. 2021; Corneli 2020; Gimon 2020)**
   - **Long contracts might better incent investment**
   - **But:**
     - **unclear alignment with spot markets;**
     - **counter-party risks;**
     - **relies on uber-IRP models**

5. ***Clean Energy forward procurement*** **(Spees et al. 2021)**
   - **Add *clean* energy auction, complementing energy & capacity:**
     - **Oblige load-serving entities to buy**
   - **Similar to "emissions cap-and-trade", but more complex (Hobbs, Bushnell, Wolak, 2010)**

Examples of California ISO's Incremental Design Changes



- ***"Energy Imbalance market"*** **(westerneim.com)**
  - **Day-Ahead "EDAM" next**
- ***Capacity market reforms*** **(CAISO, CEC, CPUC 2021)**
- ***Resource internal constraints***
  - **"State-of-charge" models**
    stakeholdercenter.caiso.com/StakeholderInitiatives/Energy-storage-and-distributed-energy-resources
- ***New reliability services/products***
  - **Network-constrained "ramp product"**
    stakeholdercenter.caiso.com/StakeholderInitiatives/Flexible-ramping-product-refinements
- ***Aggressive renewable targets***

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

Outline

I. Intro to power markets
II. Is the basic LMP framework still fit for purpose?
III. ...And what about capacity markets?
IV. Some alternatives for future designs
V. Need sound transmission & carbon policy

V. Non-market Planning & Policy Need Reform, Too!

JOHNS HOPKINS
RALPH O'CONNOR SUSTAINABLE ENERGY INSTITUTE

Because transmission, storage, DR, and supply can be interchangeable, grid reinforcements should be planned recognizing:

- **How transmission availability & pricing affect incentives for investment in resources: "*Proactive planning*"** (Sauma & Oren, 2006)

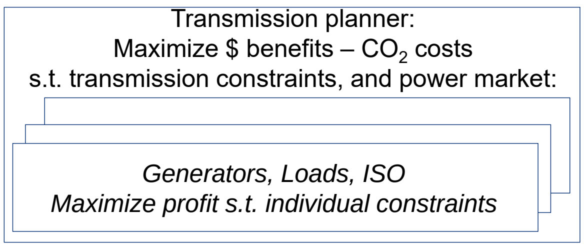
Lau & Hobbs (2021)

Can transmission planning facilitate C reductions?

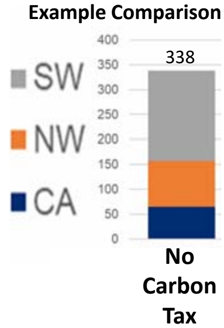
Given uncoordinated state C policies in West, can weighing CO_2 emissions in WECC transmission planning yield different plans & lower CO_2? **(Yinong Sun, Ph.D. Dissertation, JHU, in process)**

***Multilevel "second-best" model:* choose transmission additions to MIN annualized WECC-wide costs + weighted CO_2 emissions in 2034, subject to market response ("co-optimization")**

- **Assume: $40/ton social cost of CO2**



Example Comparison *(Preliminary):* System-wide CO_2 emissions (Mton)

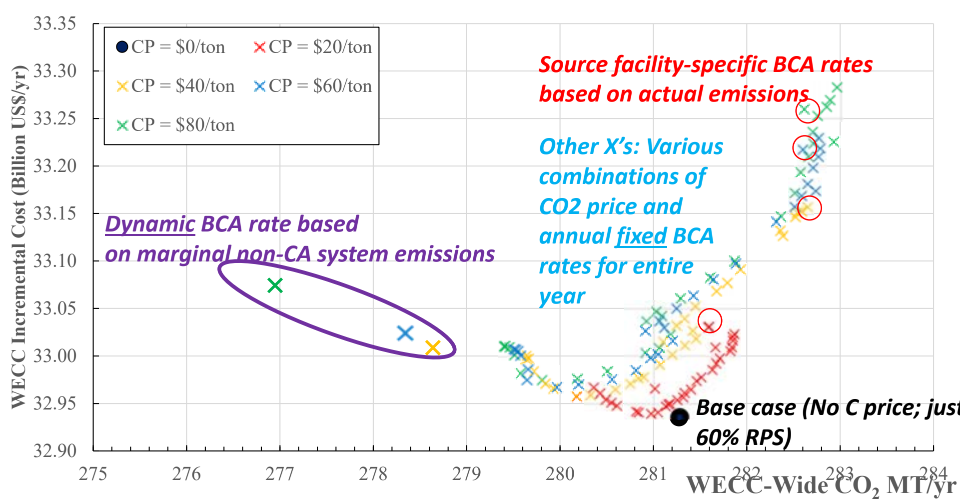


Designing effective policy: WECC Example

***Border Carbon Adjustments (BCA):* Can a state increase its C policy impact by penalizing "dirty" imports?**

Year 2034: WECC-wide CO_2 emissions & incremental power cost, under a Calif. 60% Renewable Portfolio Standard, and various:

- Calif. CO_2 prices
- BCA policies for CAISO Extended DA Market



Lesson:

- Only *dynamic* BCAs (based on marginal non-Calif CO_2) reduce emissions

Q. Xu, B. Hobbs, 2021

Conclusions

- **The SMD+ principles are still fit: New technologies don't *fundamentally challenge* LMP & RA theory**
  - Although new implementation challenges join the old ones
  - Incremental approach of CAISO justified
  - RA can be adapted to VER & storage resources availability; managing extreme events require regulatory involvement

- ***Clean energy auctions*: easiest way to inject carbon targets in long- & short-run markets**
  - Can't afford to be wasteful!

- **Market designs need to be complemented with effective & cost-efficient:**
  - Infrastructure planning
  - Carbon policy

References

- Baldick, R., Bushnell, J., Hobbs, B.F. and Wolak, F.A., 2011. Optimal charging arrangements for energy transmission. *Final Report. Project TransmiT*. Prepared for UK Office of Gas & Electricity Markets, 2011, https://web.stanford.edu/group/fwolak/cgi-bin/sites/default/files/files/OfGemReport_USTeam_Revised_2011_05_01_FINAL.pdf
- Brown, D.P., Zarnikau, J., Woo, C.-K., 2020, Does locational marginal pricing impact generation investment location decisions? an analysis of texas's wholesale electricity market. Journal of Regulatory Economics, 58(2):99–140
- Bohn, R., Caramanis, M., Schweppe, F.C., 1986, Spot Pricing of Electricity, Kluwer.
- California ISO, CEC, CPUC, 2021, Final Root Cause Analysis, Mid-August 2020 Extreme Heat Wave, Jan. 13, 2021, www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf
- California Power Utility Commission, 2018, Load Shift Working Group Report, https://gridworks.org/wp-content/uploads/2019/01/LoadShiftWorkingGroup_report_final.pdf
- Cornelli, S., 2020, A Prism-Based Configuration Market for Rapid, Low Cost and Reliable ELectric Sector Decarbonization, Dec. 16, 2020 https://files.wri.org/s3fs-public/corneli-prism-markets-for-rapid_decarbonization-final_word_version.pdf
- Cruz, M.R., Fitiwi, D.Z., Santos, S.F. and Catalão, J.P., 2018. A comprehensive survey of flexibility options for supporting the low-carbon energy future. Renewable and Sustainable Energy Reviews, 97, pp.338-353.
- Ela, E., Mills, A., Gimon, E., Hogan, M., Bouchez, N., Giacomoni, A., Ng, H., Gonzalez, J., DeSocio, M., 2021, Electricity Market of the Future, Potential North American Designs without Fuel Costs, Jan/Feb., IEEE Power & Energy Magazine,
- Ely, J., The Economics of Kludges, American Economic Journal: Microeconomics, 2011, 210-231.
- Evolved Energy, 2021, State Energy Strategy - Washington State Department of Commerce, www.commerce.wa.gov/growing-the-economy/energy/2021-state-energy-strategy/
- Frew, B.,Brinkman, G., Denholm, P., Narwade, V., Stephen, G., Bloom, A., Lau, J., 2021, Impact of operating reserve rules on electricity prices with high penetrations of renewable energy, Energy Policy, Volume 156, September 2021, 112443
- Gimon, E., 2020, Let's Get Organized! Long-Term Market Design for a High Penetration Grid, Energy Innovation, LLC., December 2020, https://files.wri.org/s3fs-public/gimon-lets-get-organized-long-term-market-design-for-a-high-penetration-grid.pdf
- Hledik, R., Faruqui, A., Lee, T., Higham, J., 2019, The national potential for load flexibility: value and market potential through 2030, https://brattlefiles.blob.core.windows.net/files/16639_national_potential_for_load_flexibility_-_final.pdf
- Hobbs, B., Bushnell, J., Wolak, F. 2010. Upstream vs. downstream CO2 trading: A comparison for the electricity context, Energy Policy, 38, 3632-3643.
- C. Kousky & R. Cooke, "Climate Change and Risk Management: Challenges for Insurance, Adaptation, and Loss Estimation," Resources for the Future, RFF-DP-09-03-REV.pdf, 2009
- Korpås, M., Botterud, A., 2020. Optimality Conditions and Cost Recovery in Electricity Markets with Variable Renewable Energy and Energy Storage. MIT CEEPR, Working paper 2020-005, http://ceepr.mit.edu/files/papers/2020-005.pdf
- Lau, J., and Hobbs, B, Electrical Transmission System Research and Development: Economic Analysis and Planning Tools, USDOE, April 2021, https://www.energy.gov/sites/default/files/2021-05/Economic%20Analysis%20and%20Planning%20Lau%20Hobbs2.pdf

References (Cont.)

- Lo, H., Blumsack, S., Hines, P. and Meyn, S., 2019, Electricity rates for the zero marginal cost grid, The Electricity Journal, 32(3), pp. 39-43.
- Lund, P.D., Lindgren, J., Mikkola, J., Salpakari, J., 2015, Review of energy system flexibility measures to enable high levels of variable renewable electricity, Renewable and Sustainable Energy Review, 45 (2015), pp. 785-807
- Mehrtani, M., Hobbs, B.F., Ela, E., Reserve and Energy Scarcity Pricing in United States Power Markets: A Comparative Review of Principles and Practices, Manuscript, Johns Hopkins University, 2022
- Mills, A.D., Levin, T., Wiser, R., Seel, J. and Botterud, A., 2020. Impacts of variable renewable energy on wholesale markets and generating assets in the United States: review of expectations and evidence. Renewable and Sustainable Energy Reviews, 120, p.109670.
- O'Neill, R.P., Sotkiewicz, P.M., Hobbs, B.F., Rothkopf, M.H. and Stewart Jr, W.R., 2005. Efficient market-clearing prices in markets with nonconvexities. European journa of operational research, 164(1), pp.269-285.
- OECD, Nuclear Energy Agency 2019, The Costs Of Decarbonisation: System Costs With High Shares Of Nuclear And Renewables, www.oecd.org/publications/the-cost of-decarbonisation-9789264312180-en.htm
- Padmanabhan, N., Ahmed, M., Bhattacharya, K., 2019. Battery energy storage systems in energy and reserve markets. IEEE Transactions on Power Systems, 35(1), pp.215-226
- Sauma, E.E. and Oren, S.S., 2006. Proactive planning and valuation of transmission investments in restructured electricity markets. Journal of Regulatory Economics, *30*(3), pp.358-387.
- Schweppe, F., 1978, "Power systems '2000': Hierarchical control strategies, IEEE spectrum, 15(7), pp. 42-47.
- Spees, K., Newell, S.A., Graf, W., 2021, Integrated Clean Capacity Market: A Competitive Market for Powering the Clean Electricity Future, The Brattle Group, January, www.nj.gov/bpu/pdf/publicnotice/Public%20Notice%20for%20RA%20Work%20Session%20on%20Clean%20Energy%20Markets.pdf
- Sepulveda, N,A. , Jenkins, J.D. , de Sisternes, F.J., Lester, R.K., 2018, Electricity Resources in Deep Decarbonization of Power Generation, Joule 2, 2403–2420, Nov. 21
- Stoft, S., 2002, Power System Economics: Designing Markets for Electricity, Wiley
- Sun, Yinong, PhD Dissertation, Johns Hopkins University, in process.
- Wang, S., N. Zheng, C. Bothwell, Q. Xu, S. Kasina, B.F. Hobbs, Crediting variable renewable energy and energy storage in capacity markets: Effects of unit commitment and storage operation, IEEE TPWRS, 2021, 617-628.
- Xu, Q., and B.F. Hobbs, "Economic efficiency of alternative border carbon adjustment schemes," Energy Policy, 2021
- Zheng, N., Qin, X.,Wu, D., Murtaugh, G., and Xu, B., Energy Storage State-of-Charge Market Model, Columbia University and CAISO, July 2022, https://arxiv.org/pdf/2207.07221.pdf
- https://zomepower.com/
- stakeholdercenter.caiso.com/StakeholderInitiatives/Energy-storage-and-distributed-energy-resources
- stakeholdercenter.caiso.com/StakeholderInitiatives/Flexible-ramping-product-refinements
- stakeholdercenter.caiso.com/StakeholderInitiatives/Energy-storage-enhancements
- westerneim.com