Retail-Level Transactive Control Linked to Wholesale LMPs

Rob Pratt
Pacific Northwest National Laboratory
robert.pratt@pnl.gov

GridWise Architecture Council
2nd Transactive Energy Workshop
IBM, White Plains, NY
March 2012

Pacific Northwest
NATIONAL LABORATORY

Multiple Operational Objectives for Transactive Dispatch of Distributed Smart Grid Assets

- Select lowest cost resources from all smart grid assets
  - Demand response (DR), distributed generation & storage (DG, DS)
- Respond to real-time (5-min.) wholesale LMP
- Manage capacity constraints at bulk level (gen./trans.)
- Manage capacity constraints at distribution level
- In the future: other value streams, other assets

Pacific Northwest
NATIONAL LABORATORY

Foundational Principles

1. Level playing field for all types of distributed SG assets
   a) Transactive, market based approach
   b) Issue: customer/3rd-party vs. utility-owned assets (retail vs. wholesale)
2. Customers participation is voluntary
   a) Opt-in to dynamic rate (or rebate)
   b) Set their level of responsiveness
   c) Rate must not penalize customers for switching to it
   d) Significant savings opportunity must be built in
3. Appropriate split of benefits between utility & customer
   a) Customer savings should reflect actual benefit provided
   b) Rate must recover required utility revenue, costs for DR
   c) Protect customer & utility against long term wholesale mkt. fluctuations
4. Simple information exchange paradigm

Design Solution (1): Real-Time Price (RTP)

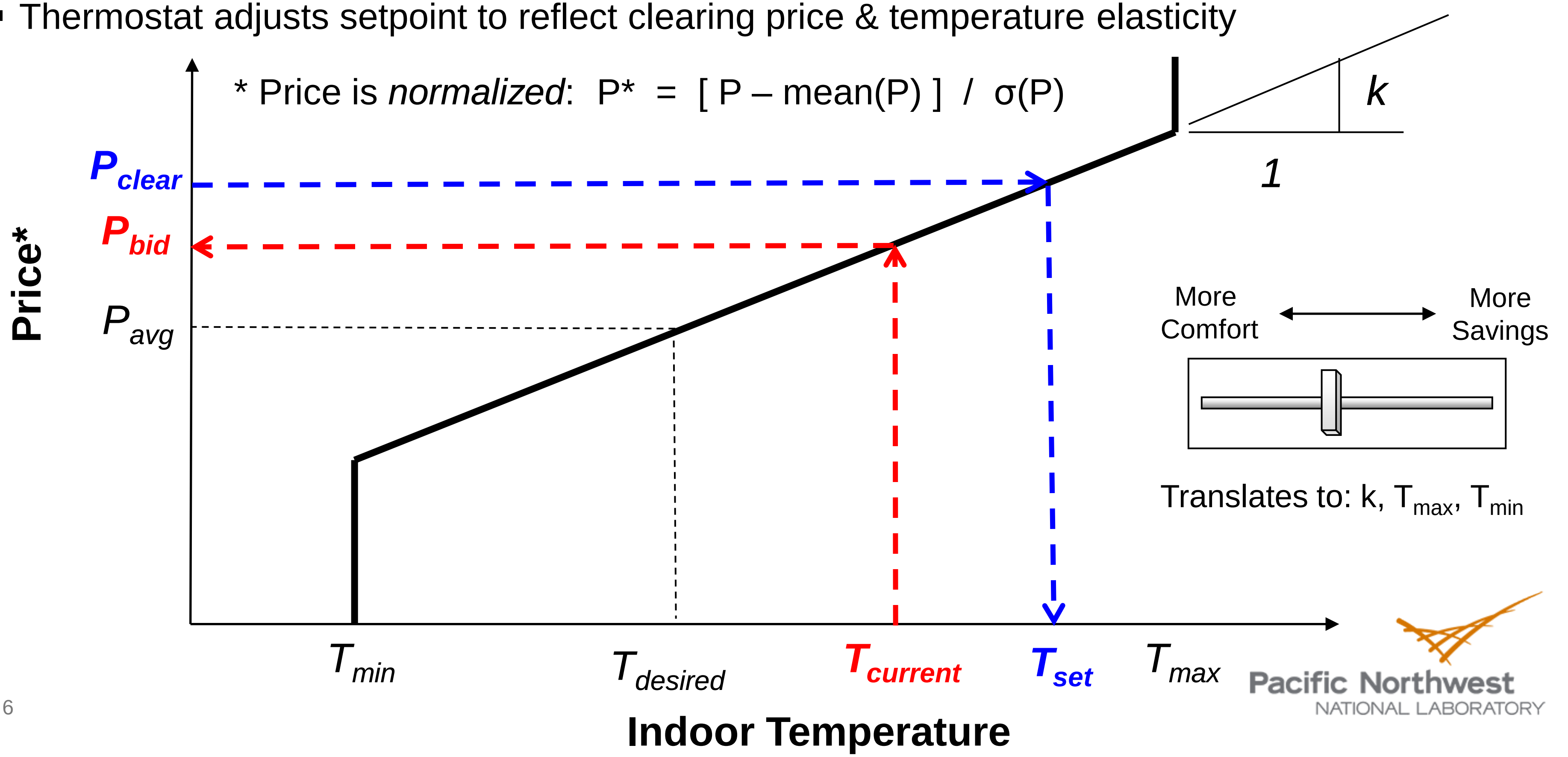
- Why RTP?
  - Better accomplish multiple objectives (wholesale & capacity)
  - Better match of retail rates to cost of service creates transparency
  - Avoid problem establishing baseline consumption for rebate approach
- Why not a time-of-use (TOU) + critical peak rate (CPP)?
  - Engage response from non-automated devices better than RTP
  - Can't be localized for dist. capacity, used for fast response w/o notice
  - TOU approximates production costs, but not market prices
  - CPP doesn't have "throttle" to match net load to avail. capacity
  - CPP requires fixed hours/days of congestion or critical-peak prices
- Could we use a peak-time rebate (PTR) instead of RTP?
  - May be more readily accepted in vertically integrated utility
  - Requires simple, transparent, accurate solution to baseline problem

Design Solution (2): Retail Double Auction for Available Capacity at each Distribution Feeder

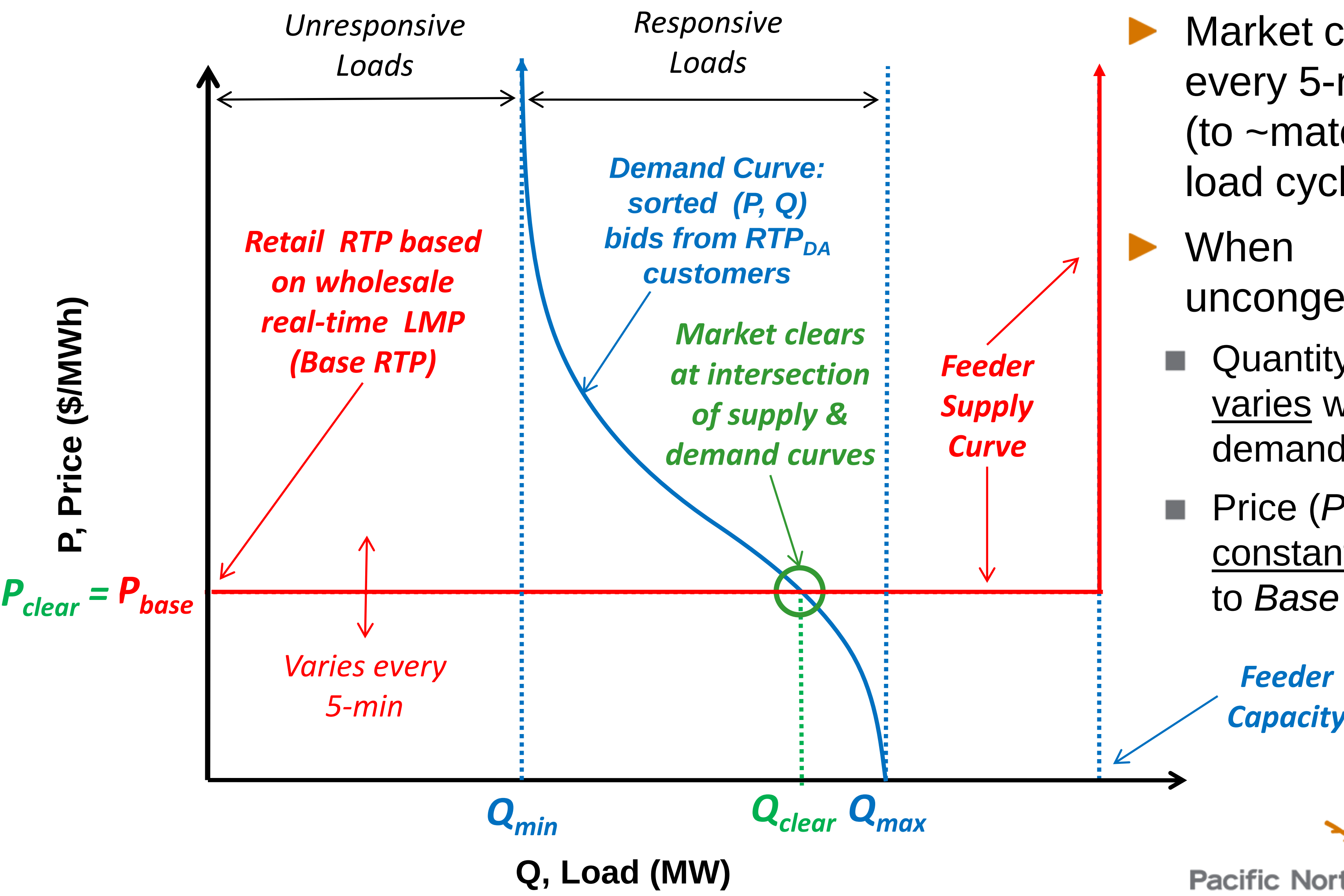
- <u>Increases</u> RTP above base price* when net demand exceeds feeder capacity, to engage distributed assets
- Each assets bids price, quantity, current state (on/off)
  - Demand curve (DR, DS-charging)
  - Supply curve (DG, DS-discharging)
- Local capacity limit reflected as max. demand in feeder supply curve
  - Price cap used to indicate all asset capacity has been exhausted
- Bulk system capacity limits imposed as further reduction in max. demand limit
  - Allocated to each feeder in proportion to SG assets, capacity margin
- Market clearing sets final price (*cleared RTP*), selects least-cost resources

Transactive Cooling Thermostat Generates Demand Bid based on Customer Settings

- User's *comfort/savings* setting implies limits around normal setpoint ($T_{desired}$), *temp. elasticity* (*k*)
- Current temperature used to generate bid price at which AC will "run"
- AMI history can be used to estimate bid quantity (AC power)
- Market sorts bids & quantities into demand curve, clears market returns clearing price
- Thermostat adjusts setpoint to reflect clearing price & temperature elasticity



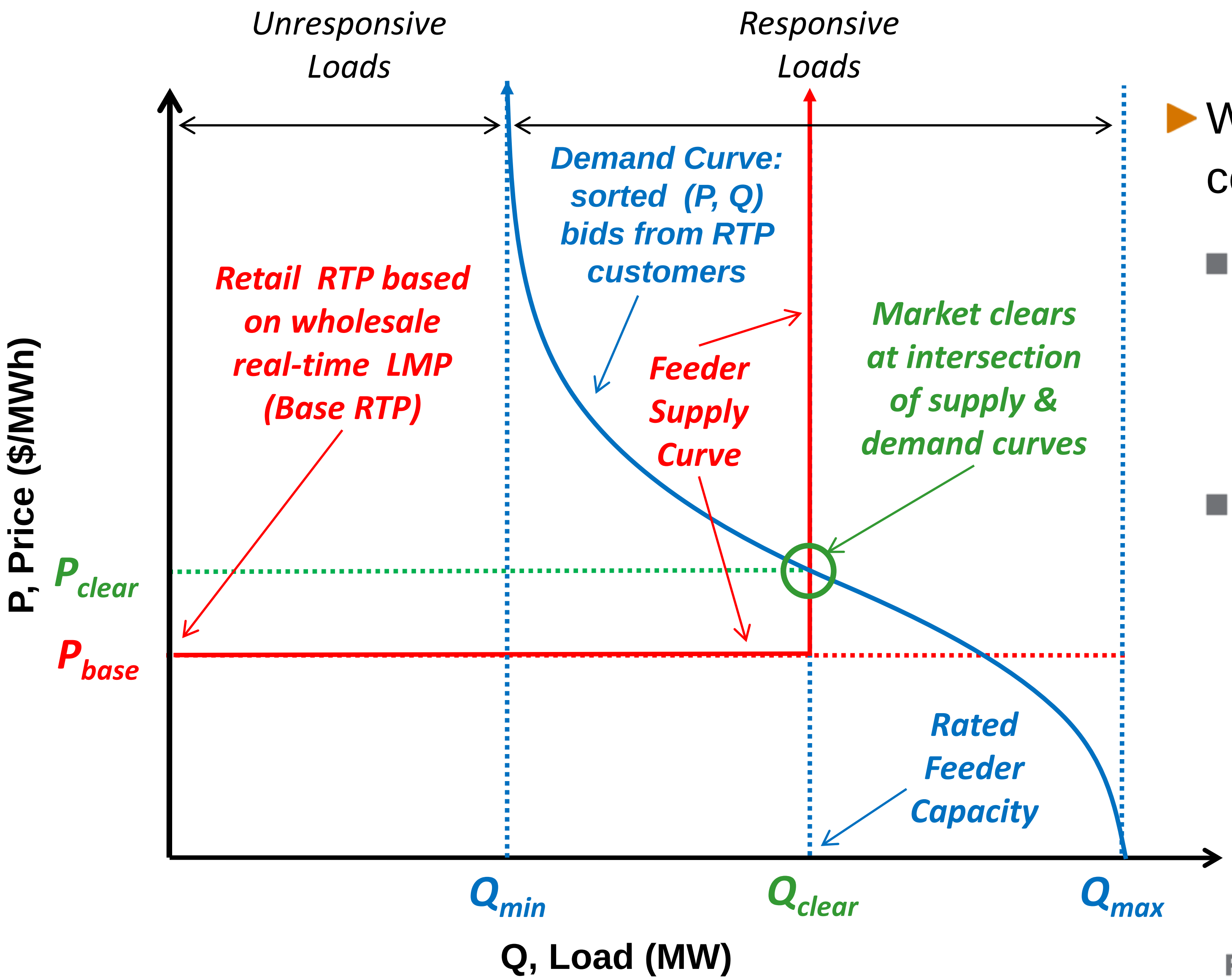
RTP Double Auction Market – *Uncongested*



- Market clears every 5-min (to ~match AC load cycle)
- When uncongested:
  - Quantity (Q_{clear}) varies with demand curve
  - Price (P_{clear}) is constant, equal to *Base RTP*

Pacific Northwest NATIONAL LABORATORY

RTP Double Auction Market – *Constrained (Feeder)*



- When constrained:
  - Quantity (Q_{clear}) is constant at rated feeder capacity
  - Price (P_{clear}) varies to keep load at rated capacity

Pacific Northwest NATIONAL LABORATORY

Challenges in Designing Transactive Rates:

Satisfying the Design Principles is Critical & Non-Trivial

Pacific Northwest
NATIONAL LABORATORY

Revenue Neutral *Base RTP*

- Revenue neutral design against current standard rate
  - I.e., for a customer with avg. annual energy & load shape (& no load shift), there is no change in annual electric bill
  - "*Your mileage may differ*" – any given customer may win or lose in relation to share of "on peak" and "off peak" consumption
  - Is this fair? Standard rates subsidize customers with "peaky" loads
- Reflects wholesale LMP only (not higher RTPs when capacity is constrained)
- Adjustment factor is developed to mitigate long-term wholesale volatility to protect utility and consumer

Why Not Build Capacity Constraint Events into the RTP Rate?

- Number of hours & days constrained is not known in advance
  - Load forecast only indicates amount of congestion
- Cleared RTPs are not known in advance, depend on interaction of:
  - Weather in any given year
  - % of peak load reduction needed to manage capacity constraint
  - Responsiveness of RTP customers
- Asset's elasticity determines clearing price
  - Amount of congestion, assets available, & elasticities vary across feeders
- Result would be *different rate design for each feeder*???

Pacific Northwest NATIONAL LABORATORY

Designing a Revenue Neutral *Base RTP*

- RTP rate designed to be *revenue neutral* prior to any load shift
  - Annual bill (*Base RTP*) = Annual bill (standard rate)
- Savings ensue from shifting load from higher to lower cost periods
- Data required is readily available
  - One+ year time-series loads from class load research sample (or AMI data)
  - Population-weights for the above
  - Wholesale LMPs from historical market data for corresponding time period
- Tariff structure in form of a regression:

$$\text{Standard Bill}_{yr} = \sum_{t(yr)} \{ a \, \text{LMP}(t) \, \text{WhlslAdj}_m + b \} \, \text{kWh}(t) + c_{yr}$$

  - a is the retail markup for LMP
  - b is the flat rate
  - c_{yr} is the annual fixed customer charge
  - WhlslAdj_m is the market adjustment factor for month m

Issues with Revenue-Neutral RTP Design

When entire customer standard bill (except customer charge) is included in the dynamic component of the RTP rate, i.e. b = 0:

- a ≈ 2 in two cases examined (utilities in ERCOT & PJM)
- Maximizes dynamic range of *Base RTP*; maximizes savings opportunity from load shifting (lower c helps, too)
- a > 1 may over reward customers for responding to wholesale prices, if response to capacity constraints is seperately incentivized (savings to utility are equivalent to a = 1)
- If utility owns no generation, a ≈ 2 may be justified
  - Wholesale energy markets absent a capacity market may not reflect true value of capacity (e.g., ERCOT)
  - Capacity market values can be captured by utility acting as aggregator

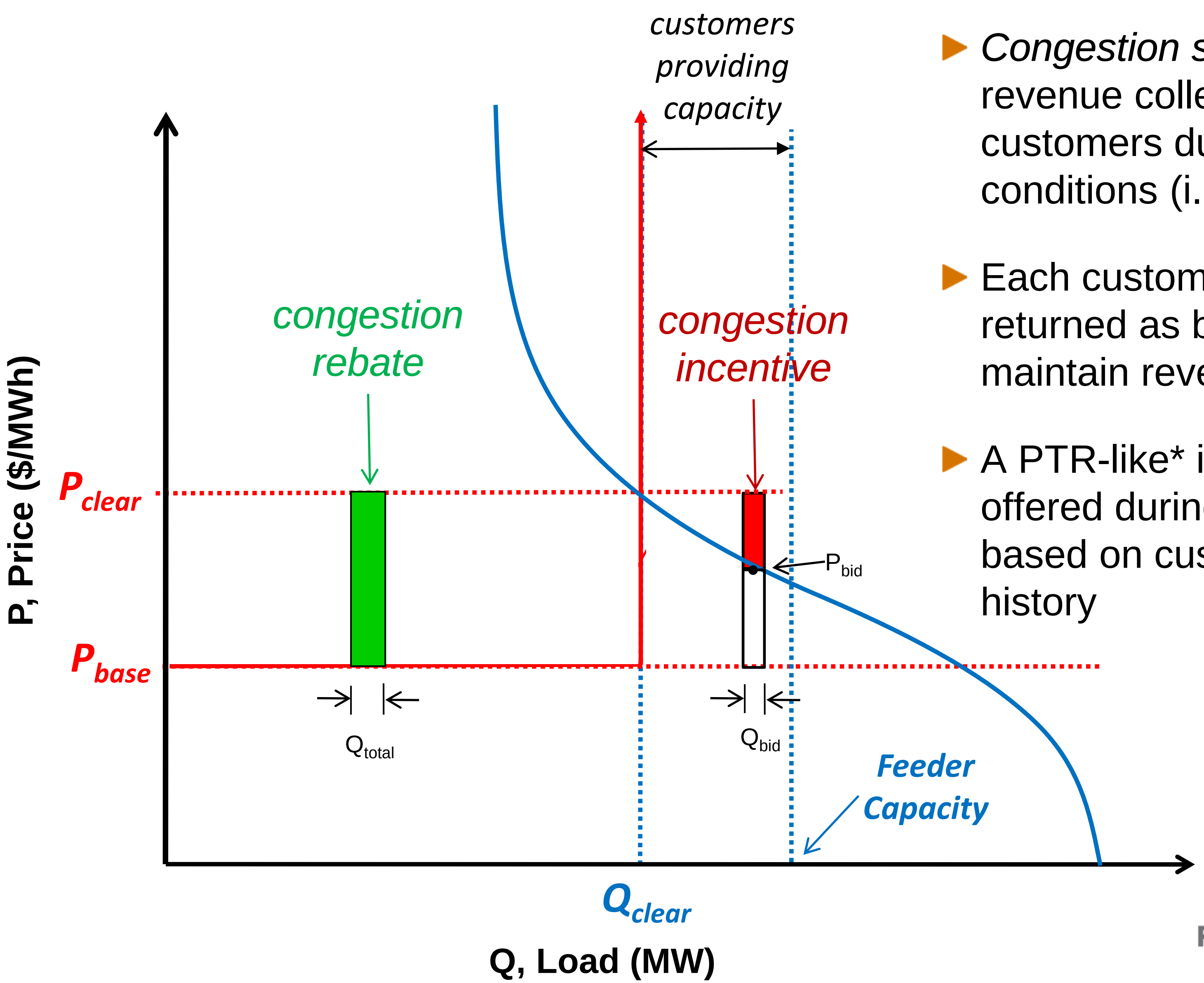
Wholesale Market Adjustment Factor

- 1st noticed when making rate based on 2009 data
  - Recession hit, PJM LMPs were very low
  - Especially real-time market – day-ahead purchases were likely biased long because of systematic forecast error
- Danger of under-recovering utility revenue requirements when LMPs are lower than those used as basis for rate
- Danger of penalizing customers when LMPs are higher than those used as basis for rate
- A monthly wholesale market adjustment factor can correct for this:

$$WhlsleAdj_m = \frac{\text{Baseline month load-weighted average LMP}}{\text{Billing month load-weighted average LMP}}$$

Pacific Northwest NATIONAL LABORATORY

What about the Congestion Surplus?



- *Congestion surplus* is extra revenue collected from customers during constrained conditions (i.e. $P_{clear} > P_{base}$)
- Each customer's surplus returned as billing rebate to maintain revenue neutrality
- A PTR-like* incentive is also offered during congestion, based on customer's bid history

* peak time rebate

Why Rebate the Congestion Surplus?

- RTP rate was designed to be revenue neutral <u>without</u> congestion
  - Customers who <u>don't</u> respond to congestion prices need to be reimbursed
  - Customers who <u>do</u> respond deserve a reward, not a penalty in the form of increased prices
- Customers on congested feeders will be subject to higher prices than peers on uncongested feeders
  - If the *congestion surplus* is not returned, they are inherently penalized, even if trying to help by being responsive

Pacific Northwest
NATIONAL LABORATORY

Other Issues

- "No loser" warranty may be required to recruit customers initially
  - Hold harmless provision guarantees a customer pays the lesser of RTP & standard rate bills (1st year only?)
  - Or, declining balance account (like Olympic Peninsula Demo)
    - energy is approximately conserved by DR load shifting
    - deposit standard rate bill into account, bill RTP against it
- Savings are seasonal, related to LMPs
  - Savings accrue in off-peak season (bad customer optics)
  - Suggests customers sign up for a year, declining balance account
- Complications from declining & inclining block rates
- <u>Impossible to share attractive savings if the business case is not there</u>

Extra Slides

Demonstrations of Transactive Control Underway

- AEP's gridSmart™ stimulus funded demonstration project
  - ~1,000 residential customers will be recruited
  - RTP/double-auction rate design (tariff) approved by Ohio PUC
  - Technical performance & customer engagement to be compared with other DR program types (DLC, TOU, CPP, etc.)
  - Software engine for market operation, HEM-based thermostat bidding, & billing under construction
- Pacific Northwest Smart Grid Demonstration
  - Extending transactive control to link generation, transmission, & distribution nodes in hierarchical architecture
  - Monetizes operational objectives from generation to end-use (e.g., integration of wind)
  - Addressing interoperability & cyber-security issues

www.aeopohio.com/save/demoproject *www.pnwsmartgrid.org*

Future Objectives for RTP Transactive Design

- Reduce wholesale LMPs (not just react to them)
  - Bid distributed assets into wholesale market
- Provide regulation
- Provide spinning reserve
- Provide intra-hour balancing/ramping, esp. re. renewables
- Forecast of prices would improve asset control strategies, especially batteries (see NW Demo)
- Include other assets
  - Distribution volt-VAR control can provide VARs to bulk system
  - Electric vehicle charging, V2G (require forecast)