Energy Systems Integration Group
Charting the Future of Energy Systems Integration and Operations

Probabilistic Forecasts: *Are We Finally Ready to Use Them?*

Benjamin F. Hobbs

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Chair, CAISO Market Surveillance Committee

ESIG, Denver, June 4, 2019

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SOLAR ENERGY TECHNOLOGIES OFFICE
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Thanks to CAISO Staff, my sponsors & SF2 colleagues Warren Powell, Jean-Paul Watson, Ignacio Arevena, Qingyu Xu, Robin Hytowitz, Elina Spyrou, who can't be blamed

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Outline

I. Why probabilistic?

II. Five approaches in ISO markets
- Role of probabilistic solar / wind forecasts
- Pros & Cons

III. Possible use of probabilistic forecasts: Demand curve for CAISO flexible ramp

Why not model deterministically?

- Huge uncertainties…and they are growing

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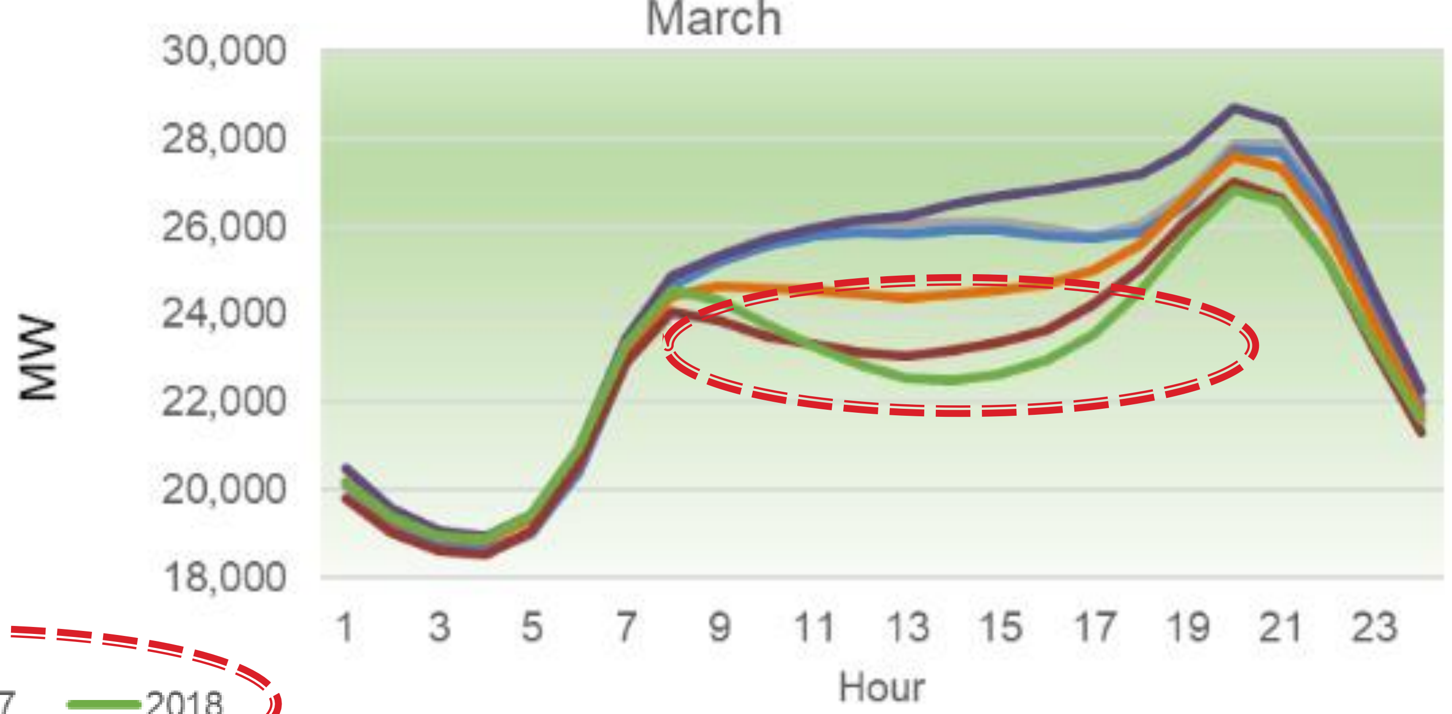
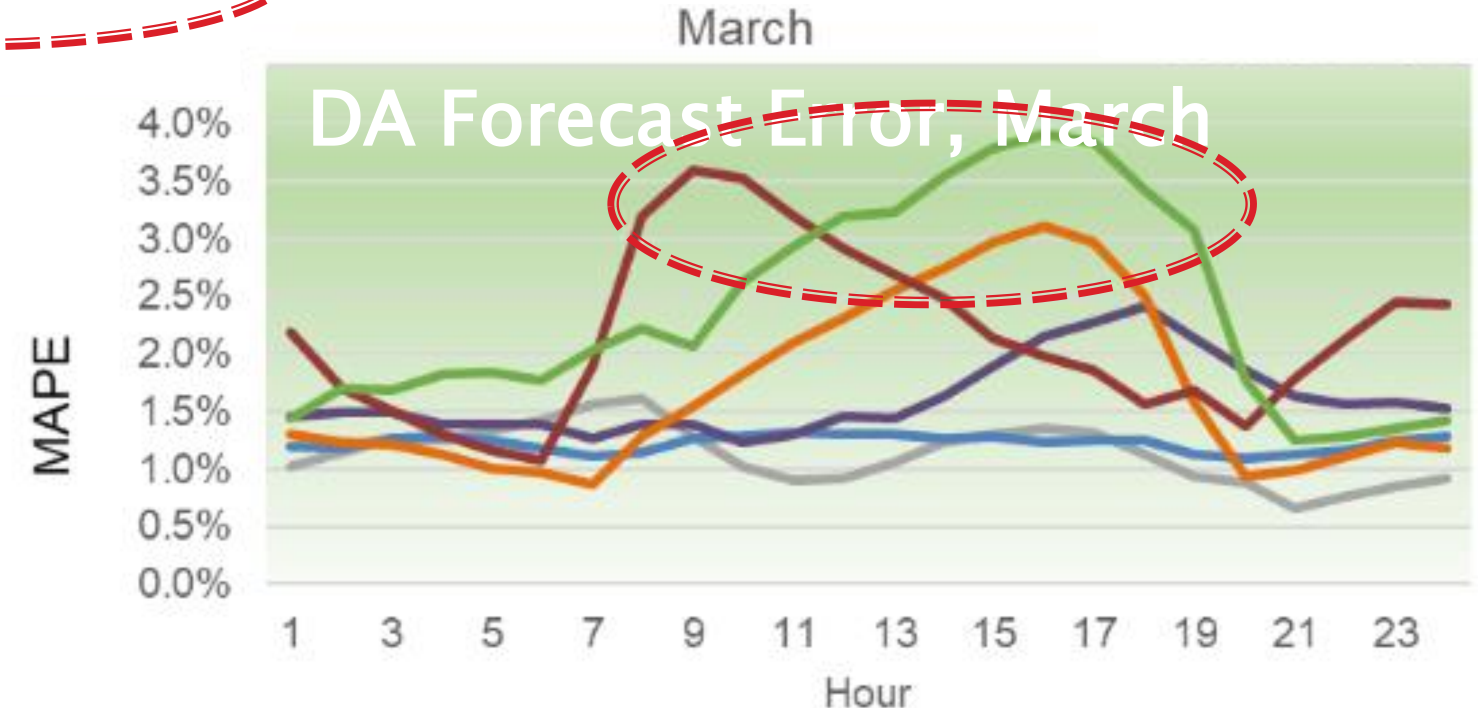
BTM Solar→ Increases CAISO Load Forecast Error

A. Motley, www.caiso.com/Documents/Briefing-Day-AheadLoadFor



2013 2014 2015 2016 2017 2018

California ISO



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Why not model deterministically?

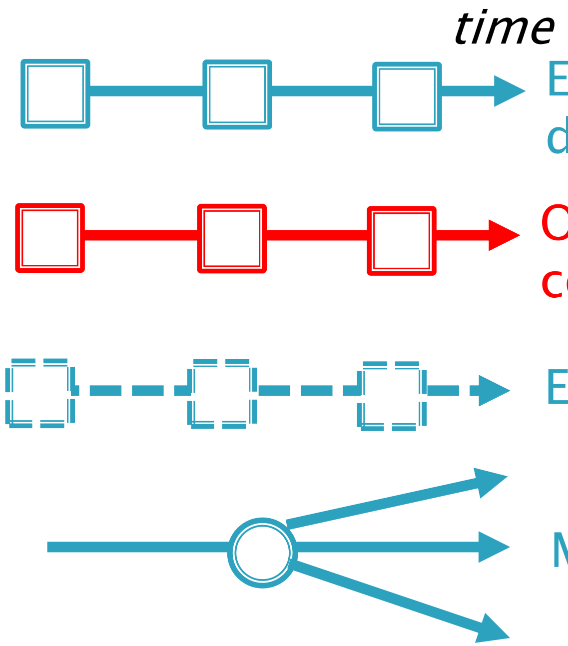
- Huge uncertainties…and they are growing
- Flaw of averages
  - Planning under certainty leaves you vulnerable, undervalues options/flexibility
  - Makes a practical difference in decisions & performance

Decades	Years	Months	Days	Hours	Minutes
Resource, Transmission Investment (*see Marc Ahlstrom's surprises*)	Price Long-term Contracts	Equipment replacement, stockpiling spares	Hydro Storage Operation	Unit Commitment	Dispatch

II. Approaches to including uncertainty in spot market designs

(Powell, Meisel, *IEEE TPWRS*, 2016; Daraeepour, Patino-Echeverri, Conejo, *Energy Econ.*, 2018)

Key



Energy Forecast (with cost-based dispatch decisions)

Other products (with cost-based commitment decisions)

Energy Forecast (feasibility decisions only)

Multiple energy scenarios

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II. Approaches to including uncertainty in spot market designs

(Powell, Meisel, *IEEE TPWRS*, 2016; Daraeepour, Patino-Echeverri, Conejo, *Energy Econ.*, 2018)

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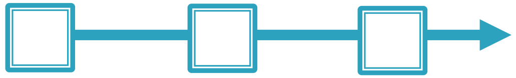
- ISO implementations/proposals:
  1. Simple Deterministic → let market parties self-hedge



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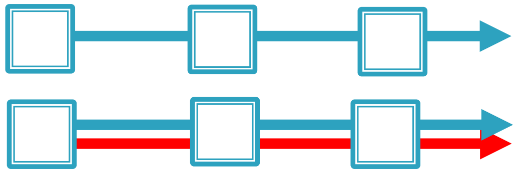

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  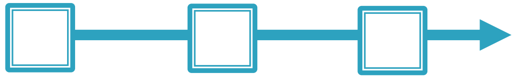
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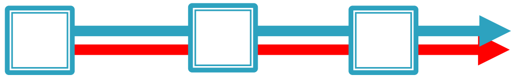
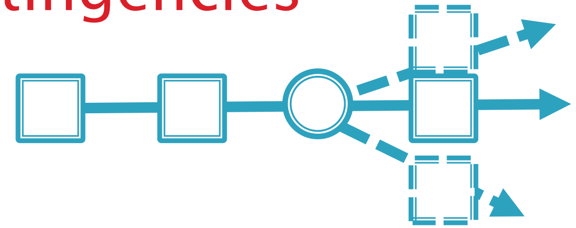
  
  3. Deterministic + Maintain feasibility under explicit contingencies
     - No post-contingency cost



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  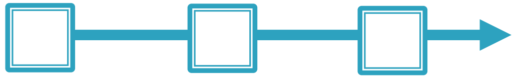
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  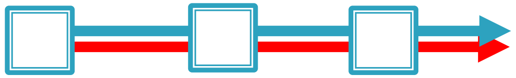
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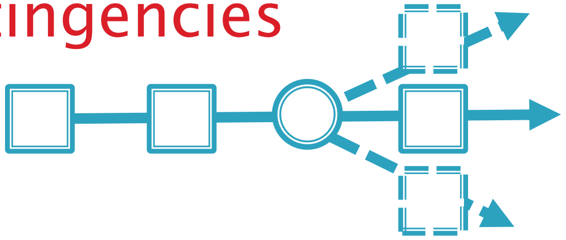
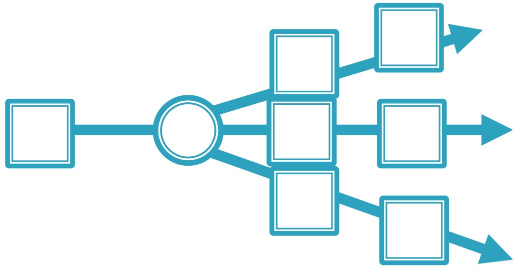
  
  4. Multiple scenarios & probabilistic
     - 2-stages

       here-and-now decision

       → *uncertainty resolved*

       → *wait-and-see decision*
     - Multistage
  

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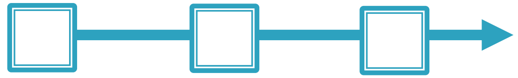
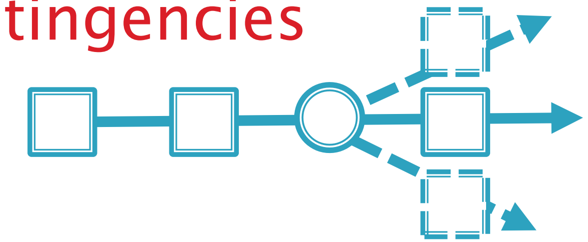
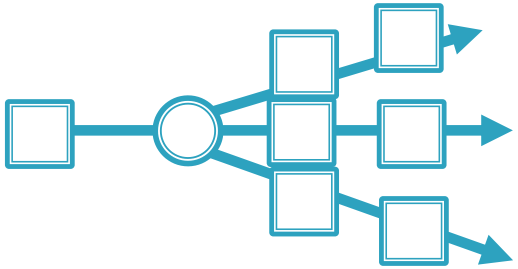
     - 2-stages
       here-and-now decision
       → *uncertainty resolved*
       → *wait-and-see decision*
     - Multistage
  5. Synthesis



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- ISO implementations/proposals:
  1. Simple Deterministic → let market parties self-hedge
  2. Deterministic + Reserve products
  3. Deterministic + Maintain feasibility under explicit contingencies
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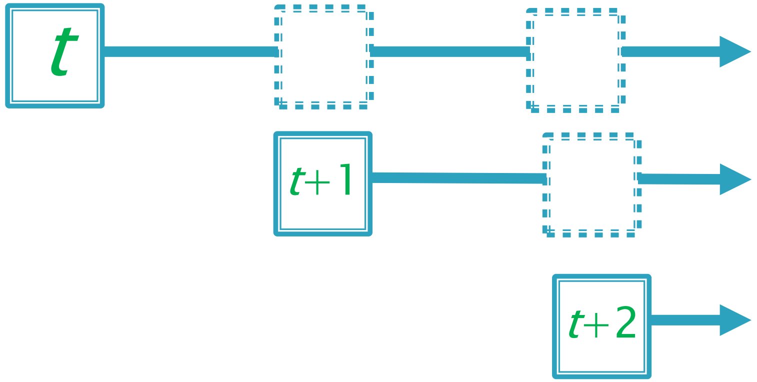
  5. Synthesis

- Features of all ISO implementations/proposals
  - Mix of approaches
  - Multisettlement (DA/RT)
  - Rolling horizon (settlement & advisory intervals)



1. Simple deterministic + self-hedging

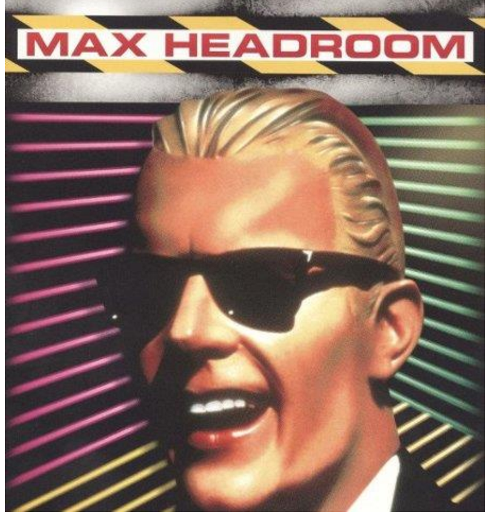
(Kazempour, Hobbs, Value of flexible resources, virtual bidding, and self-scheduling in two-settlement electricity markets with wind generation, *IEEE TPWRS*, 2018)

momonline.blog/2018/01/15/taking-the-blinders-off/

- Basics:
  - ISO runs deterministic DA market for energy based on forecast net load
    - Parties can self-schedule
    - Virtuals shift supply/demand to RT
  - RT settles imbalances when uncertainties resolved
- Roles of probabilistic forecasts:
  - Market parties use them to increase profits and (indirectly) market efficiency (*Listen to Rob Gramlich!*)
  - Need to derive RT price distributions from net load probs
- Pros:Transparency/simplicity makes room for other complications in market models
- But: Inefficiencies occur if too much inflexible/too little flexible capacity committed
  - *Yet if* virtual bidders correctly characterize distribution of RT prices, then:
    - Can eliminate *most*—but not all--inefficient commitments
  - *If* slow-start units self-commit and project RT price distributions, then:
    - *(Nearly) all* inefficiencies eliminated

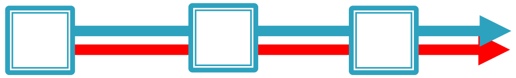
2. Deterministic + reserve products

(Holtinen et al., TPWRS 2013)



www.shoutfactory.com/product/max-headroom-the-complete-series

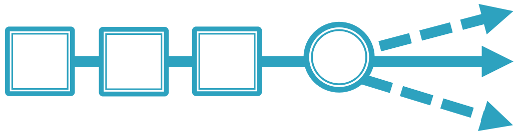
- Basic:
  - ISO runs deterministic DA/RT markets for energy based on forecast,
  - … and also acquires **capacity** reserves
    - Reserves can be dispatched economically or according to rules in RT
    - Types: RUC, flexiramp, spin contingency-only, non-spin, replacement, reg-up, reg-down, …
- Roles of probabilistic forecasts: ISO sets reserve requirements based on:
  - Quantile of distribution
  - *Ex ante* B-C balancing of alternative requirements (Ortega-Vazquez & Kirschen, TPWRS, 2008)
  - *Endogenous* B-C balancing within market software (demand curve) (CAISO Flexible Ramp)
  - Dynamically update based on latest probabilities (Matos and Bessa, TPWRS, 2012)
- Pros:
  - Transparency/simplicity if not too many products, & extensive experience
  - A few reserves can cover multitude of scenarios
    - "Allow extra travel time"
- But as markets accrue kludges, reserves may be both over-simplified and overly complex:
    - →Rube Goldbergian
    - Miss important contingencies
    - Become undeliverable



3. Deterministic & contingency feasibility

www.imdb.com/title/tt2017038/mediaviewer/rm3761101056

- Basic:
  - ISO runs deterministic DA/RT markets for energy based on forecast,
  - … and also include contingency constraints, including:
    - Contingency *flow* feasibility: Operating point still feasible under n-1, other contingencies



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Contingency modeling enhancements

The ISO currently uses exceptional dispatches and minimum online capacity constraints to return the ISO system to its reliable operating limit after real-time contingencies occur. This initiative will explore proactive market alternatives to restore the operating limit.

Initiative status

Tariff development: Pending
Board of Governors approval: Dec 14, 2017

Contingency modeling enhancements - relevant market notices

Current meeting

No meeting scheduled at this time.

Policy development

Contingency modeling enhancements - papers and proposals

Addendum Draft Final Proposal - Contingency Modeling Enhancements 8/29/2017 14:45

raisedonhoecakes.com/ROH/new-homeland-security-rule-legit-or-camels-nose-under-the-tent/

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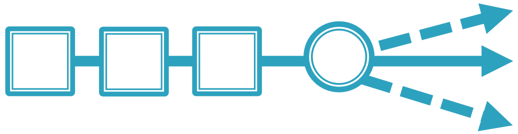
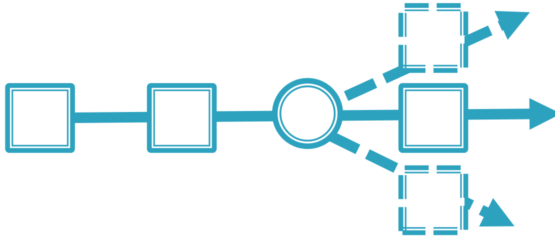
- Basic:
  - ISO runs deterministic DA/RT markets for energy based on forecast,
  - … and also include contingency constraints, including:
    - Contingency *flow* feasibility: Operating point still feasible under n-1, other
    - Contingency *dispatch+flow* feasibility: Post-contingency redispatch to meet criterion

- Role of probabilistic forecasts: ISO could define plausible scenarios of extreme net loads, and ensure feasibility of redispatch in each

- Pros:
  - Endogenize location and amount of *deliverable* reserves,
    - Perhaps lower cost than *ex ante* reserve products

- But:
  - Curse of dimensionality: Huge # scenarios, which ones?
  - Successive uncertainties (multistage) not considered
    - uncertainty assumed completely resolved post-contingency
  - Without probabilities, extreme yet highly unlikely cases may wag the dog
  - Diminished price transparency

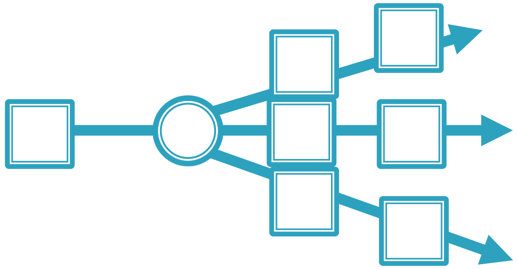




4. Probabilistic scenarios

http://s.hswstatic.com/gif/how-make-decisions-1.jpg

- Basic:
  - ISO optimizes market under multiple scenarios
  - Objective is *probability*–weighted cost
  - "Non-anticipativity" enforced for *here-and-now* decisions
  - *Wait-and-see* decisions: one set per scenario
- Role of probabilistic forecasts: Random draws
  - Time series, perhaps branching trees (Pinson et al., *Wind Energy,* 2009)
  - Can oversample extreme events
- Pros:
  - Theoretically simple: eliminates need to proliferate capacity products
    - Mark O'Malley: "*It's about supply-demand balance*"
  - Endogenizes location & amount of *deliverable* reserves, perhaps at much lower cost than products
- But:
  - No profitability guarantee
  - Curse of dimensionality
  - If sensitive to probabilities, then how to specify?
  - Variables & timing might not fit ISO timelines



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5. Synthesis

(Watson et al., and Ela et al., FERC Software Conference, 2018; V Dvorkin, S Delikaraoglou *IEEE TPWRS*, 2019)

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- **Scheduling & pricing:** Reserve/Contingency-based market model
  - Simplicity
  - Can augment with robust optimization for RUC (ISO-NE)
  - Could include extreme cases as contingencies or probabilistically
- **Situational awareness; Inform selection of reserves & contingencies** by off-line stochastic analysis
  - *Dynamically update* reserve requirements/demand curves based on today's weather
  - *Check deliverability* of reserves, based on likely congestion patterns
  - Run *advisory* intraday/RT stochastic optimization, translate solution into reserves for market runs

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III. Example: CAISO Flexible Ramp Product

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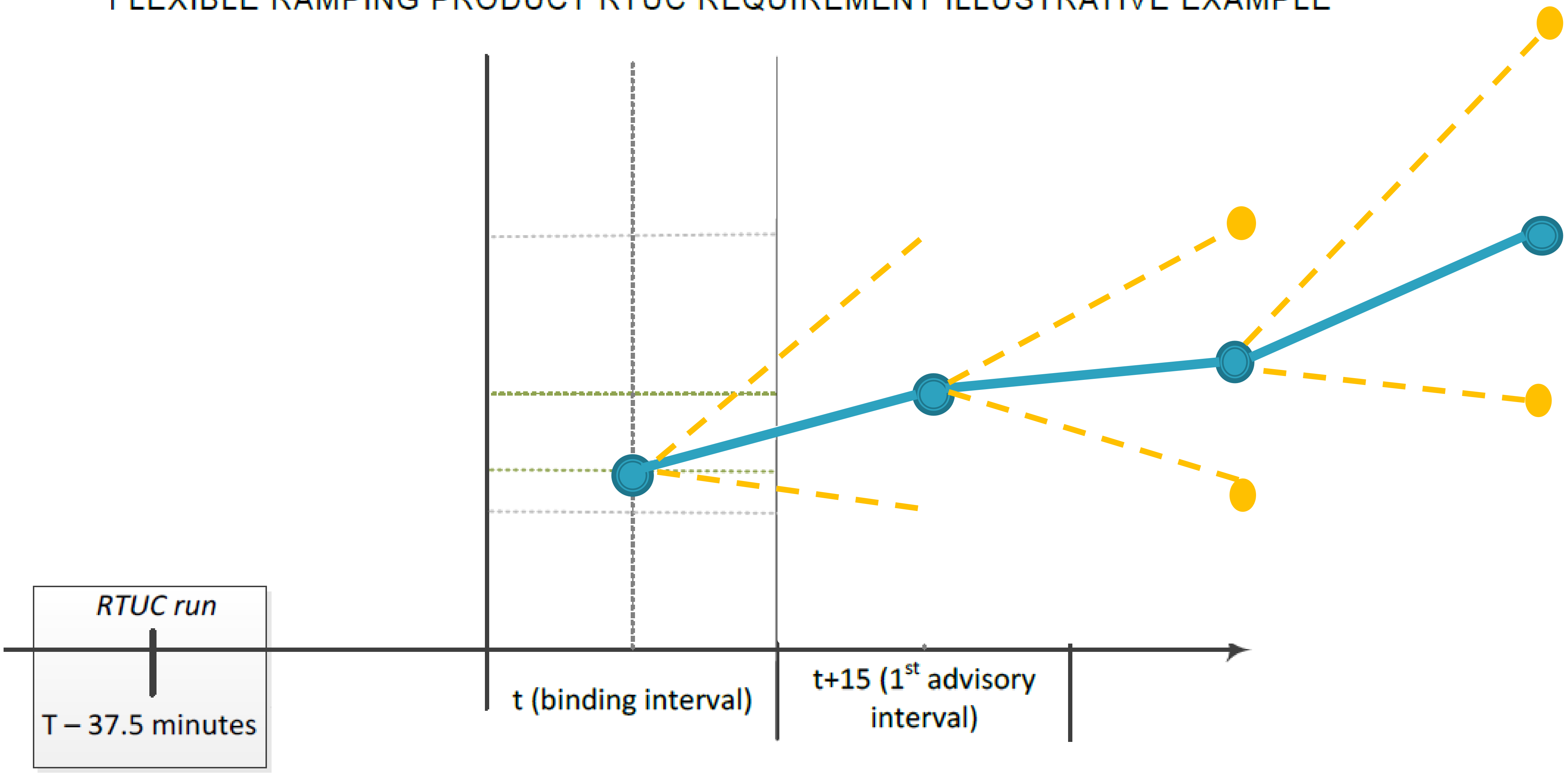
FLEXIBLE RAMPING PRODUCT RTUC REQUIREMENT ILLUSTRATIVE EXAMPLE



Expected Histogram Sample used to Calculate Uncertainty Requirement for EIM Area -- January 25, 2018

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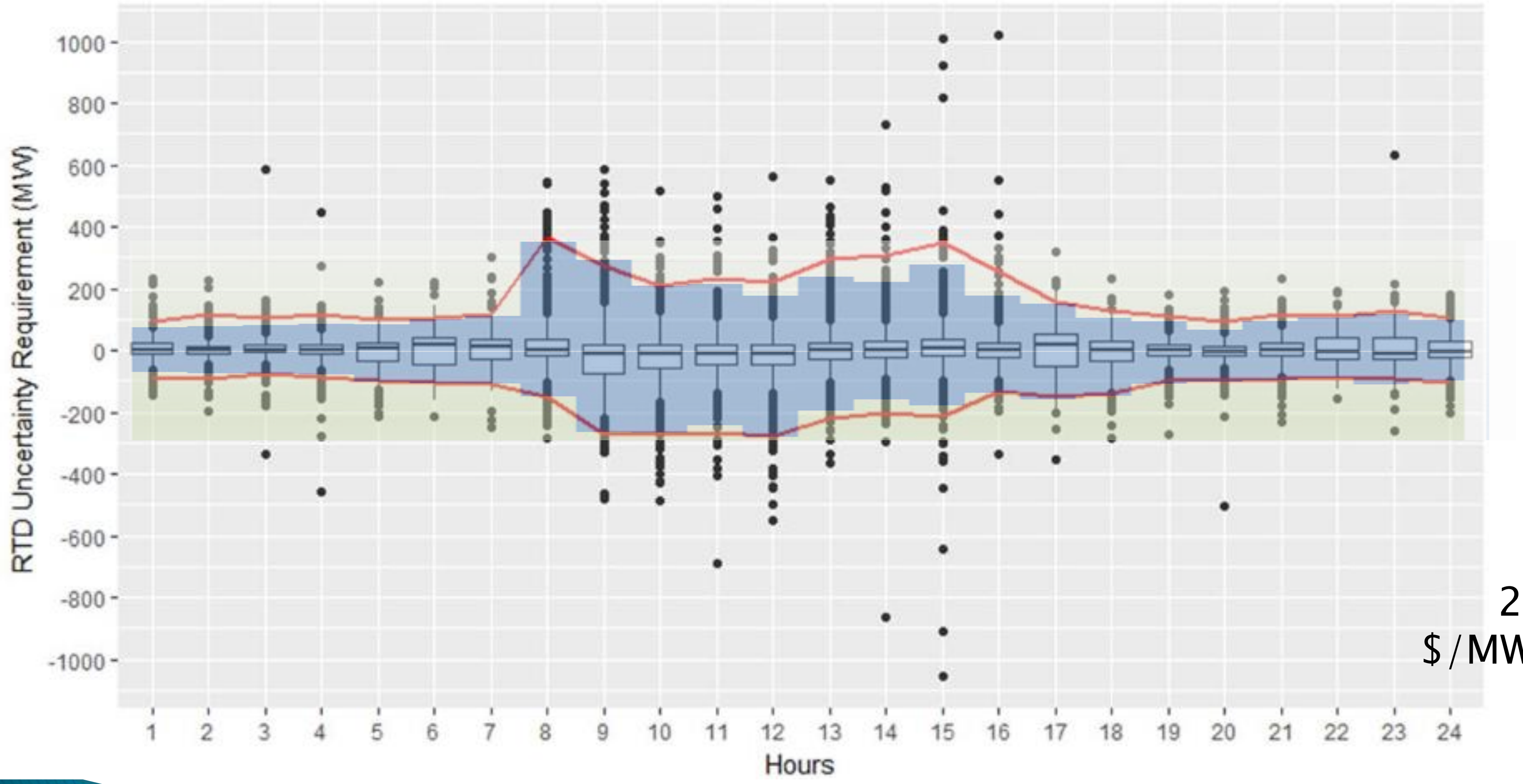
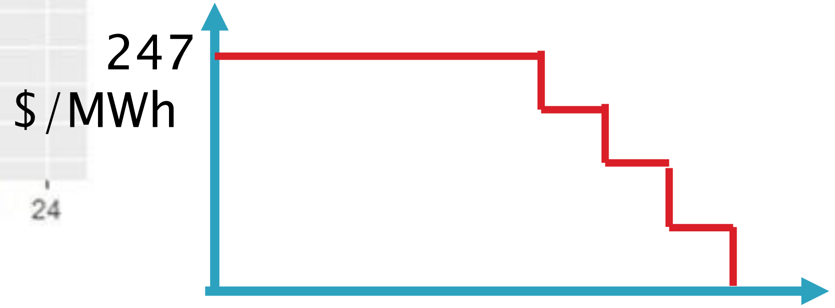
http://www.caiso.com/Documents/AgendaandPresentation-MarketPerfomanceandPlanningForum-Feb202018.pdf





Data of rolling window of 40 days (weekdays) and 20 days (weekends) → Demand Curves Calculation

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Constructing the Flexible (Up) Ramp Product Demand Curve: CAISO 15 Minute Market (FMM)

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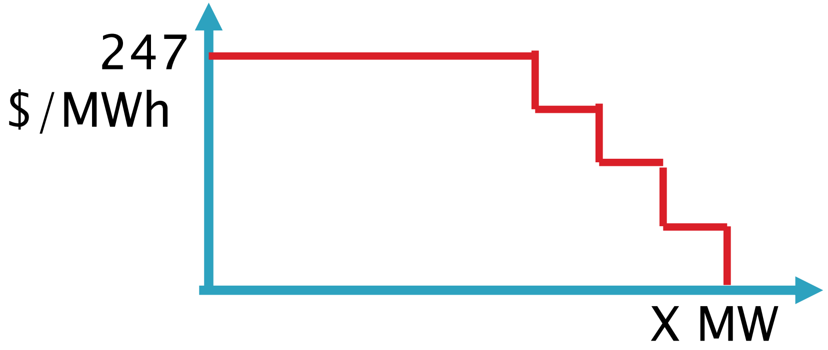
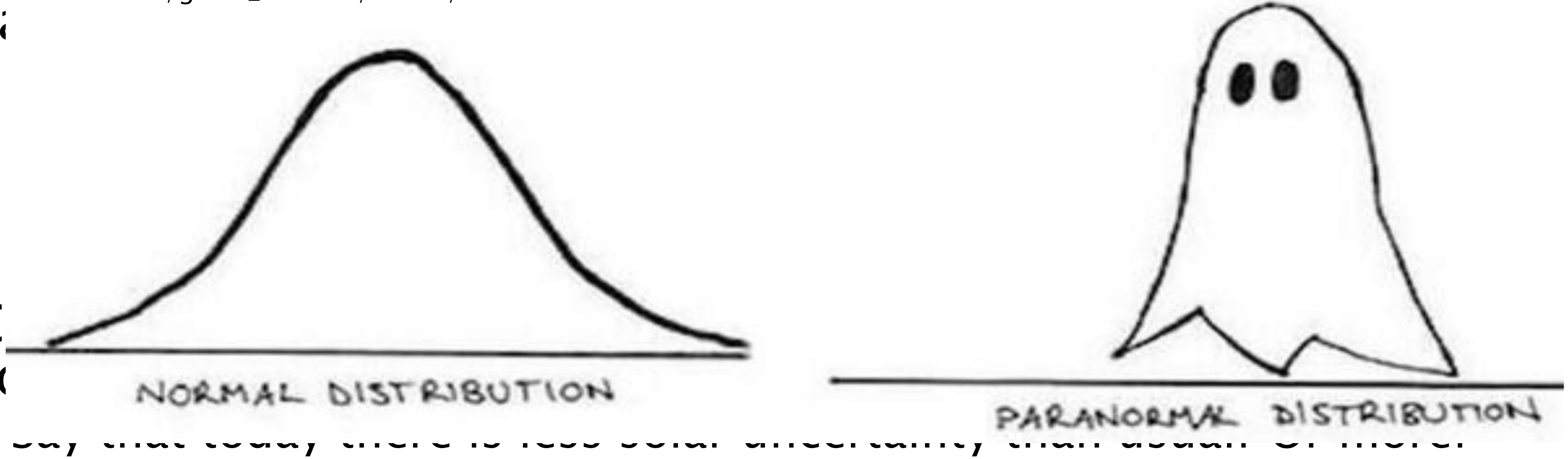
- *First*, probability analysis
  - If X = amount of up-ramp capability scheduled at *t*…
    … what's the prob of load balance violation (LBV) at *t*+15 in FMM?
  - Let NL(*t*) = FMM Settlement Interval Net Load *forecast* in interval *t*
  - $P(LBV|X) = P\{NL(t+15) > NL(t)+X\}$
    $= P\{NL(t) + E(\Delta NL(t,t+15)) + \boldsymbol{\epsilon}(15) > NL(t)+X\}$
    $= P\{\boldsymbol{\epsilon}(15) > X - E(\Delta NL(t,t+15))\}$
  - **ϵ(15)**'s distribution depends on load, BTM gen, & grid-scale wind & solar
- *Then*, expected cost
  - If cost of LBV = \$1000/MWh → marginal worth of 1 more MW of X is P(LBV)*1000/hr
  - Assume
    - marginal value is zero if P(LBV) is <2.5%
    - ceiling of \$247



Whence ϵ(15)'s Distribution?

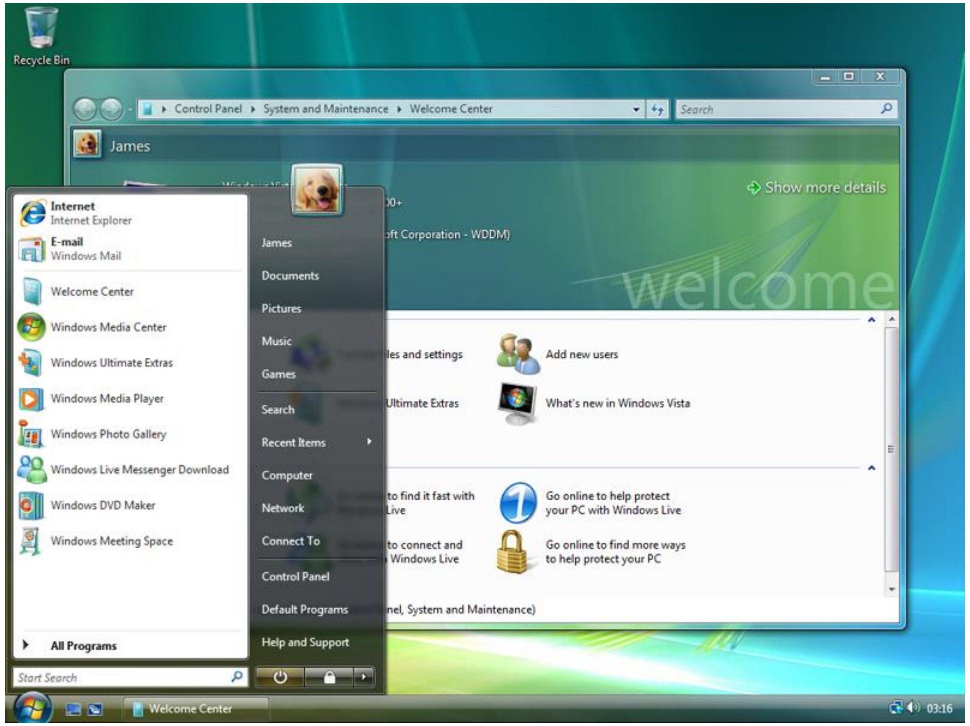
twitter.com/grave_matters/status/480705820041433088

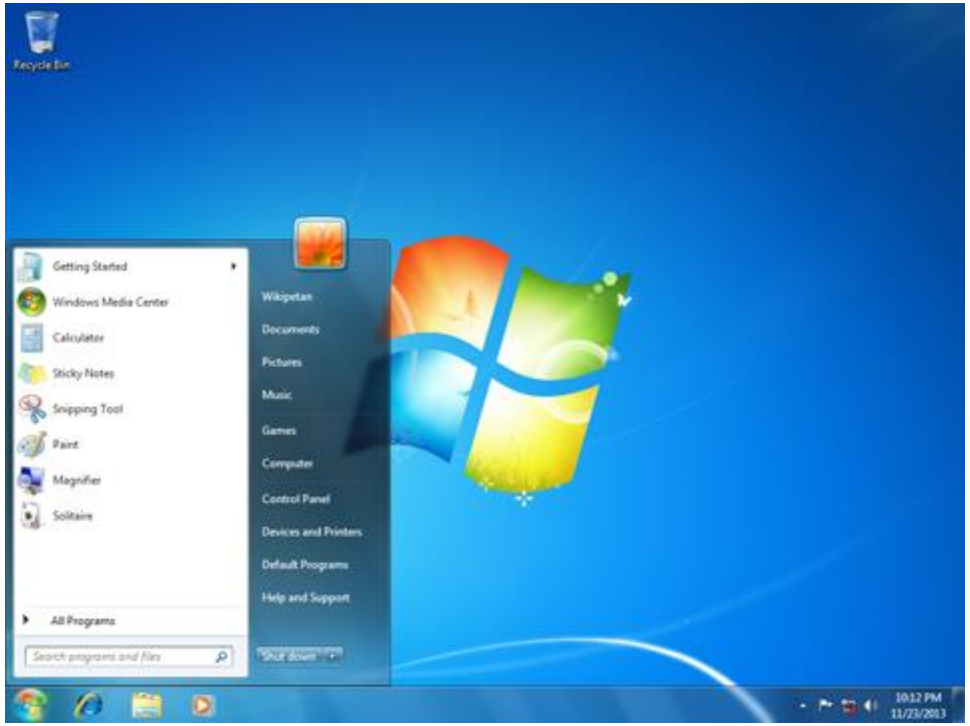


- Pa
  - ... or $t+15$)
    ... 5)
  -
  -
- C ... nd and
  sc
  -
- A possible approach:
  - Overall variance = SUM component variances + covariance terms
  - Modify overall variance: replace 40-day variances of component forecast errors…
    - …With today's variances, based on probabilistic forecasts
    - Then rescale histogram consistent with updated overall variance

Challenges

- Market Design:
  - *When do we reach the “Windows Vista” moment?*





Challenges

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- Market Design:
  - *When do we reach the "Windows Vista" moment?*
  - Consequences of load imbalances not understood
- Use of Probabilistic Forecasts:
  - Data, data, data ….
  - Integration in market products
    - E.g., Lag may differ from what market products require
      - NWP errors 2-4 hrs ahead
      - But CAISO markets use 37.5, 52.5, …, 217.5 minute forecasts for FMM
        - Plus 7.5, 15, 22,5…., 67.5 minute forecasts for dispatch
  - Correlations of components depend on weather
  - BTM solar particularly sticky, given its growth & unobservability

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Curious?
Questions?

www.fuelyourwriting.com/start-the-story-where-do-we-begin-01-25-10/

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