2016 BC HYDRO WIND INTEGRATION STUDY

TRC KICK-OFF MEETING

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April 1, 2015

MEETING OUTLINE

• Welcome/Introduction/Study Overview	8:30 – 9:05
• System, Market and Modeling Overview	
• General Overview of BC Hydro	9:05 – 9:20
• BC Hydro Generation System Operation Overview	9:20 – 9:50
• Market Transactions and NWPP Initiatives	9:50 – 10:20
• **BREAK (10:20 – 10:35)**	
• BC Hydro Operations Planning Models Overview	10:35 – 11:05
• Study Methodology	
• Part 1 – Incremental Reserve Requirements and Cost	11:45 – 11:50
• **LUNCH (11:50 – 12:45)**	
• Part 1 Continued (Discussion)	12:45 – 13:15
• Part 2 – Day-ahead Opportunity Cost	13:15 – 14:30
• **BREAK (14:30 – 14:45)**	
• Input Data and Scenarios	14:45 – 15:30
• General Discussion and Feedback from TRC	15:30 – 16:15
• Next Steps	16:15 – 16:30

STUDY OBJECTIVE

- Update the wind integration cost
- Assess the impacts on system operations of integrating higher levels of wind power

MEETING OBJECTIVE

- Initiate engagement with the TRC
- Describe study approach
- Establish and agree on the general direction of the work required

WIND INTEGRATION COST

What it is

- A cost adder applied to wind projects in integrated resource planning and acquisition processes to account for the additional cost to integrate wind into the system
- Create level playing field for all resource options

What it is NOT

- A fee charged to wind proponents

PREVIOUS WIND INTEGRATION STUDIES

- Phase I (2008) – high level, preliminary analysis
  - $10/MWh
- Phase II (2010) – detailed modeling study
  - Continue to use $10/MWh in 2013 IRP

Scenario Combination	Operating Reserve Costs ($/MWh)		Day Ahead Opportunity Costs ($/MWh)		Total Cost ($/MWh)	
	F2011	F2021	F2011	F2021	F2011	F2021
CAPEX 15% (1,500 MW)	6.5	6.3	4.3	6.4	10.8	12.7
CAPEX 25% (2,500 MW)	7.7	7.5	7.9	11.9	15.6	19.4
CAPEX 35% (3,500 MW)	7.3	7.0	6.3	9.6	13.6	16.5
High Diversity, 15% (1,500 MW)	3.4	3.2	2.0	2.8	5.4	6.0
High Diversity, 25% (2,500 MW)	3.6	3.5	2.7	3.7	6.3	7.3
High Diversity, 35% (3,500 MW)	4.4	4.3	3.2	4.2	7.6	8.5

- Proposed 2016 study approach based on 2010 study, but with some updates/modifications

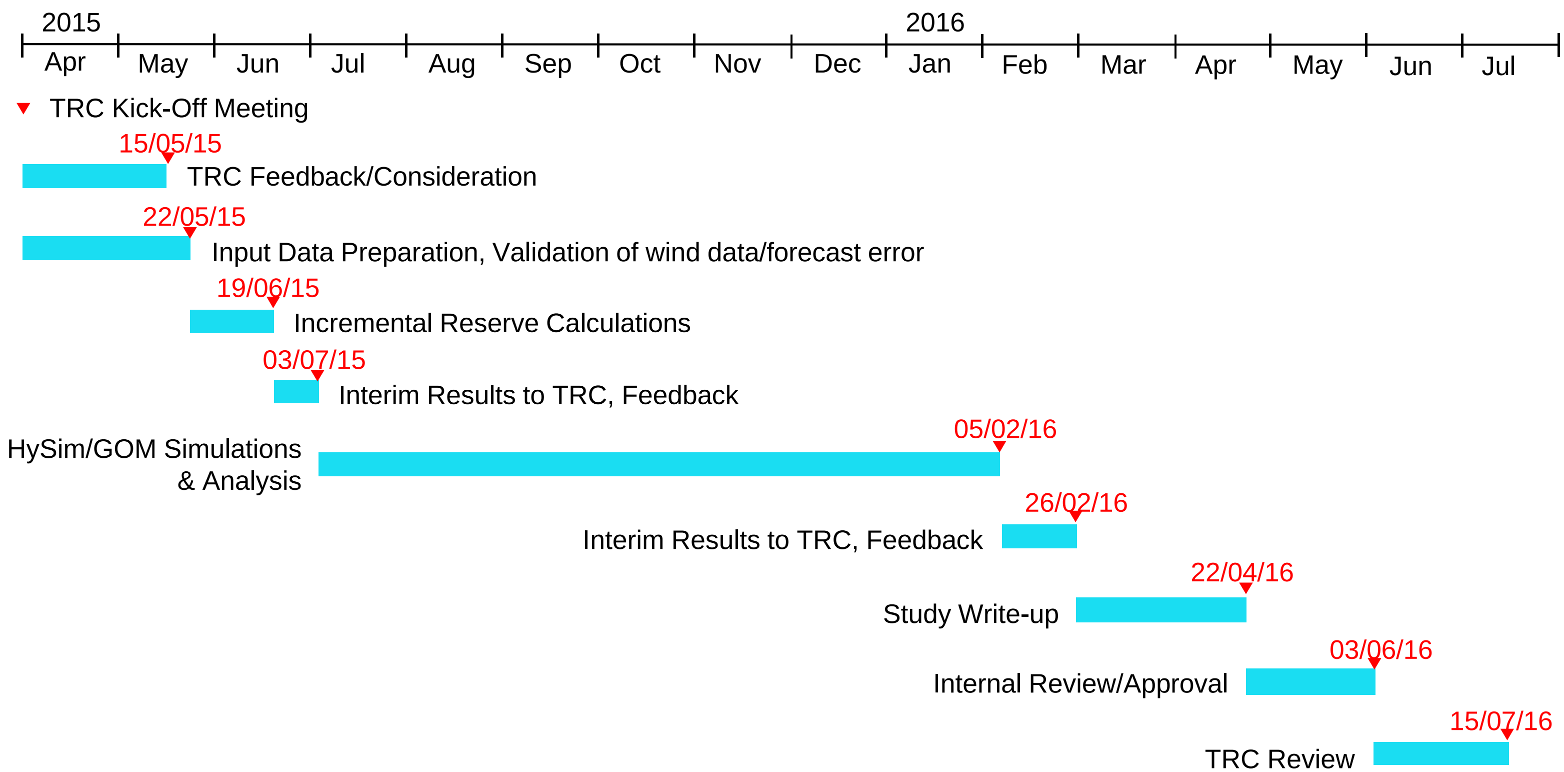
PROJECT PLAN

Task	Objective	Approach/Steps	Deliverables
TRC feedback/ consideration	Finalize study approach/ methodology and data sources	Consider feedback from TRC received during and following kick-off meeting; internal discussions	Finalized study methodology and data sources
Input data preparation/ validation	To prepare input data used in the reserve calculations and model simulations	• Update wind data (3TIER) • Validate simulated wind characteristics/ DA forecast error • Create resource portfolio using SO • Create wind generation time series for each wind scenario • Create 1-min wind generation time series • Finalize other assumptions (water & load data, prices, etc)	• Summary report on wind data/ DA forecast error validation • Wind generation time series for each wind scenario (including 1-min data) • Other input data

PROJECT PLAN

Task	Objective	Approach/Steps	Deliverables
Incremental capacity reserve calculations	Calculate regulating, load-following and imbalance reserves for all wind scenarios	Statistical approach	Regulating, load-following and imbalance reserves for all wind and market transactions scenarios
HySim/GOM Simulations & Analysis	• Calculate within hour reserve and day-ahead opportunity costs for each scenario • Determine system impacts	• Prepare input files for HySim and GOM • Run HySim to prepare boundary conditions for GOM • Run GOM for each scenario • Analyze output for costs and system impacts	• With-in hour reserve costs for each scenario • Day-ahead opportunity costs of each scenario • Analysis of system impacts
Study Write-up	Produce draft report	Write report	Draft study report
Internal review/approval	To finalize report	Review draft report	Final study report
TRC review	TRC to comment on study approach/ methodology	Review final report	Memorandum from TRC

PRELIMINARY STUDY TIMELINE



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STAKEHOLDERS

- On-going engagement process with Clean Energy BC and CanWEA on wind
- Update stakeholders on methodology & results

SYSTEM, MARKET AND MODELING OVERVIEW

GENERAL OVERVIEW OF BC HYDRO

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BC HYDRO

- Crown corporation
- Vertically integrated utility
- 1.9 million customers
- 31 hydroelectric facilities, 3 thermal generating plants
- ~12,000 MW installed generating capacity
- 18,000 km transmission lines
- Interties to Alberta and US
- Winter peaking load

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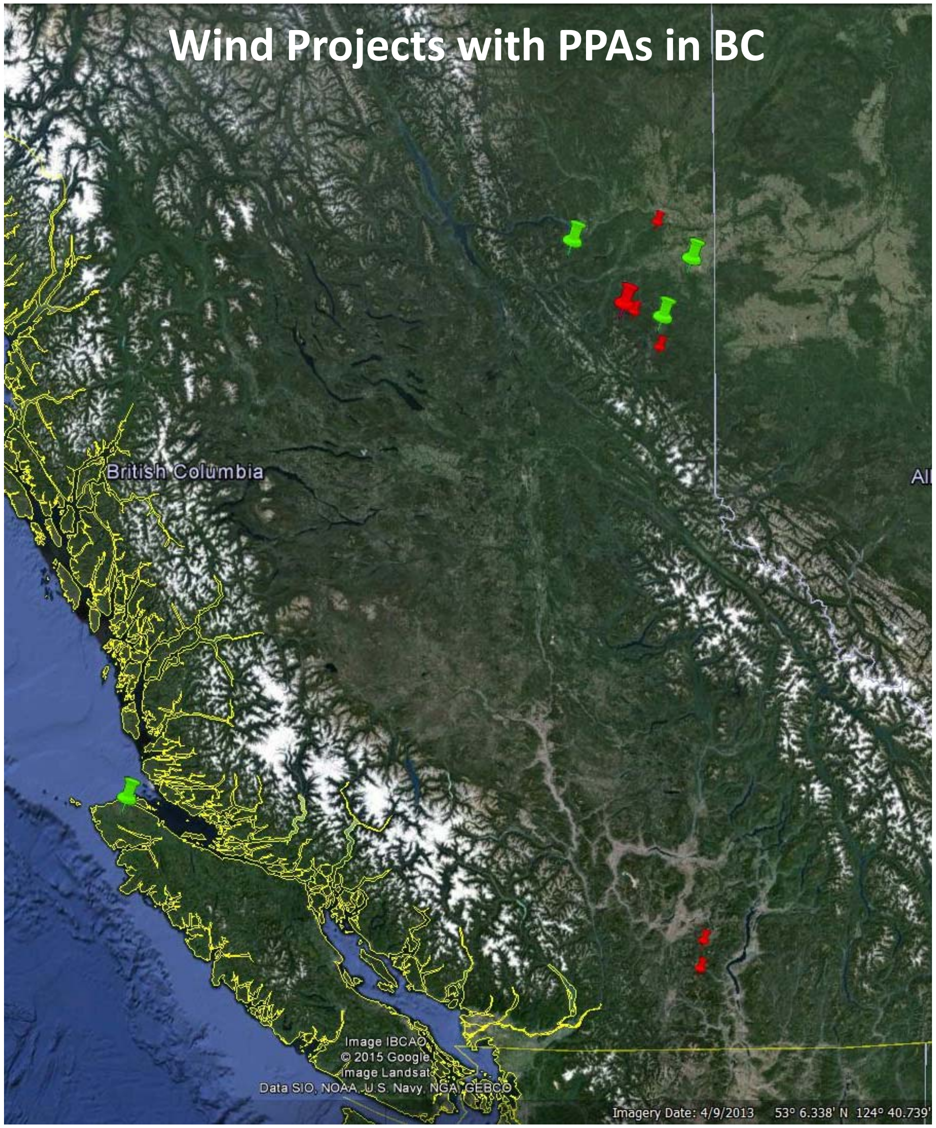
IPP GENERATION

Clean Energy from Independent Power Producers (IPPs) form a substantial part of BC Hydro's generation mix.

- Includes run-of-river, wind and biomass
- 92 projects (~3,900 MW) operating in BC, another 32 projects (~1,400 MW) with PPAs
- IPPs supply ~20% of domestic energy need

Contracted Wind

- 5 projects with PPAs through competitive call processes (672 MW)
- 5 projects with PPAs through Standing Offer Program (75 MW)



BC HYDRO GENERATION SYSTEM OPERATION OVERVIEW

GORD BRADLEY
GENERATION OPERATIONS

This presentation has been removed as it contains commercially sensitive information.

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ENERGY TRANSACTIONS & NWPP INITIATIVES

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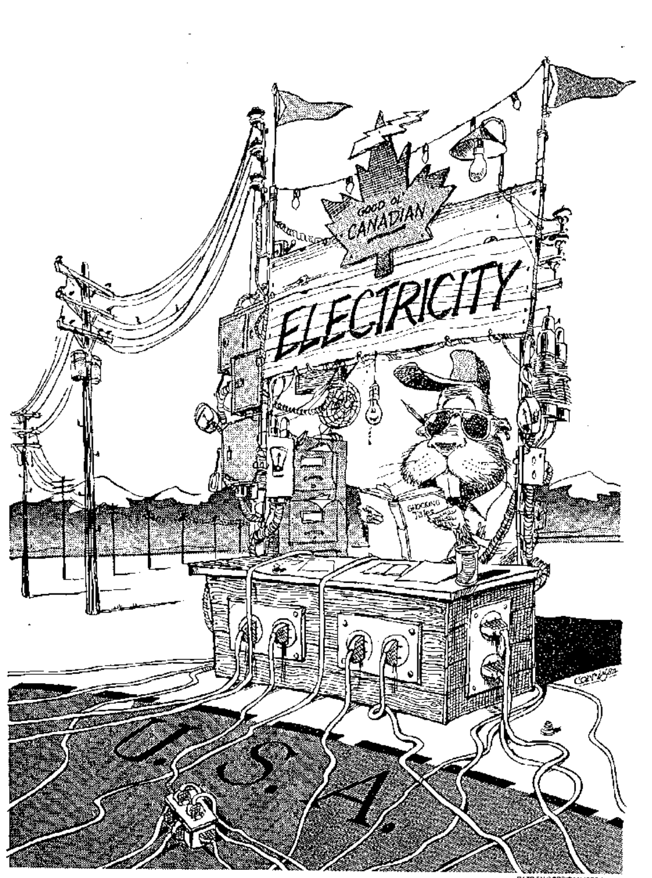
OUTLINE

1. Introduction to Markets in the NW
   - No Clearing Market in BC
   - Timescales of Transactions
2. Energy Imbalance Markets & SCEDs - what are they trying to achieve
3. CAISO EIM
4. NWPP Market Coordination Initiative

NO CLEARING MARKET IN BC



TIMEFRAMES & VOLUMES OF TRANSACTIONS IN THE NWPP

Trading Timeframes:

- Day Ahead, Real-Time; Intra-hour–30min & (as of 2014) 15 minute scheduling

Volumes:

- Vast majority of energy in the US Northwest is traded as multiple hour or single hour blocks of energy
- Intra-hour *scheduling* as of Spring 2014 was very modest:
  - Approximately 0.4% of etags are intra-hour etags (NW)
  - Approximately 0.01% of etagged MWHr volume is intra-hour (NW)

Limited bilateral and no organized capacity markets in the Northwest, hence standard transactions include both energy & capacity.

TODAY'S WORLD IN THE NWPP

- Active trading and scheduling *generally* achieves efficient generation / transmission use
  - But largely limited to <u>hourly</u> granularity
    - Fifteen minute scheduling recently enabled, but low trading liquidity
- Intra-hour imbalances due to
  - Difference between scheduled hourly load and actual load
  - Difference between scheduled hourly VER output and actual VER output
- Imbalances served within each Balancing Authority Area (BAA) independently
  - Able to "net" imbalances <u>within</u> BAA, but not <u>between</u> multiple BAAs
  - Each BAA's net imbalances generally served by BA's set aside dispatchable resources

Mass installation of VERs has resulted in growing concerns that today's framework for meeting intra-hour imbalances is highly inefficient and must change.

ENERGY IMBALANCE MARKETS / SCEDS: WHAT ARE THEY TRYING TO ACHIEVE?

Centralized Visibility and Dispatch

1. **Diversity of imbalances across multiple BAAs**
   - Energy efficiency – allow offsetting imbalances to net each other
   - Capacity efficiency – avoid carrying duplicative balancing reserves, diversity *may* reduce total balancing reserves necessary to maintain reliability
2. **Least-cost dispatch**
   - Meet the <u>net</u> multi-BAA imbalance from lowest-priced resources, not just from specific balancing reserves set aside
   - Additional, mutually-beneficial trading opportunities that bilateral trading may miss
3. **Other features of many EIMs / SCEDs**
   - Actual flow model instead of contract path improves transmission utilization
   - Centralized "unit commitment" – dispatch thermal units to start-up and be ready
   - Congestion relief – use EIM / SCED to re-dispatch resources to resolve congestion

CAISO HOSTS THE FIRST EIM IN THE WESTERN INTERCONNECTION

- PacifiCorp joined the CAISO EIM in Fall 2014
- Nevada plans to join the CAISO EIM in 2015
- PSE plans to join the CAISO EIM in 2016

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CAISO EIM – POTENTIAL BENEFITS

1. Diversifies imbalances across multiple BAAs
   - Energy and capacity efficiencies possible through ‘netting’ offsetting imbalances
2. Least-cost dispatch
   - Provides least-cost approach to meet net imbalances
3. Unit commitment
   - Position and start flexible resources
4. Actual flow model and congestion relief
   - More efficient utilization of transmission network through improved modelling
   - Use EIM to re-dispatch generation to resolve congestion
5. Low cost and fast implementation
   - Leverages existing software, processes, staff of CAISO
   - No explicit exit fee
6. Potential for coordinated dispatch across Western Interconnection under a single EIM

CAISO EIM – KEY CONCERNS

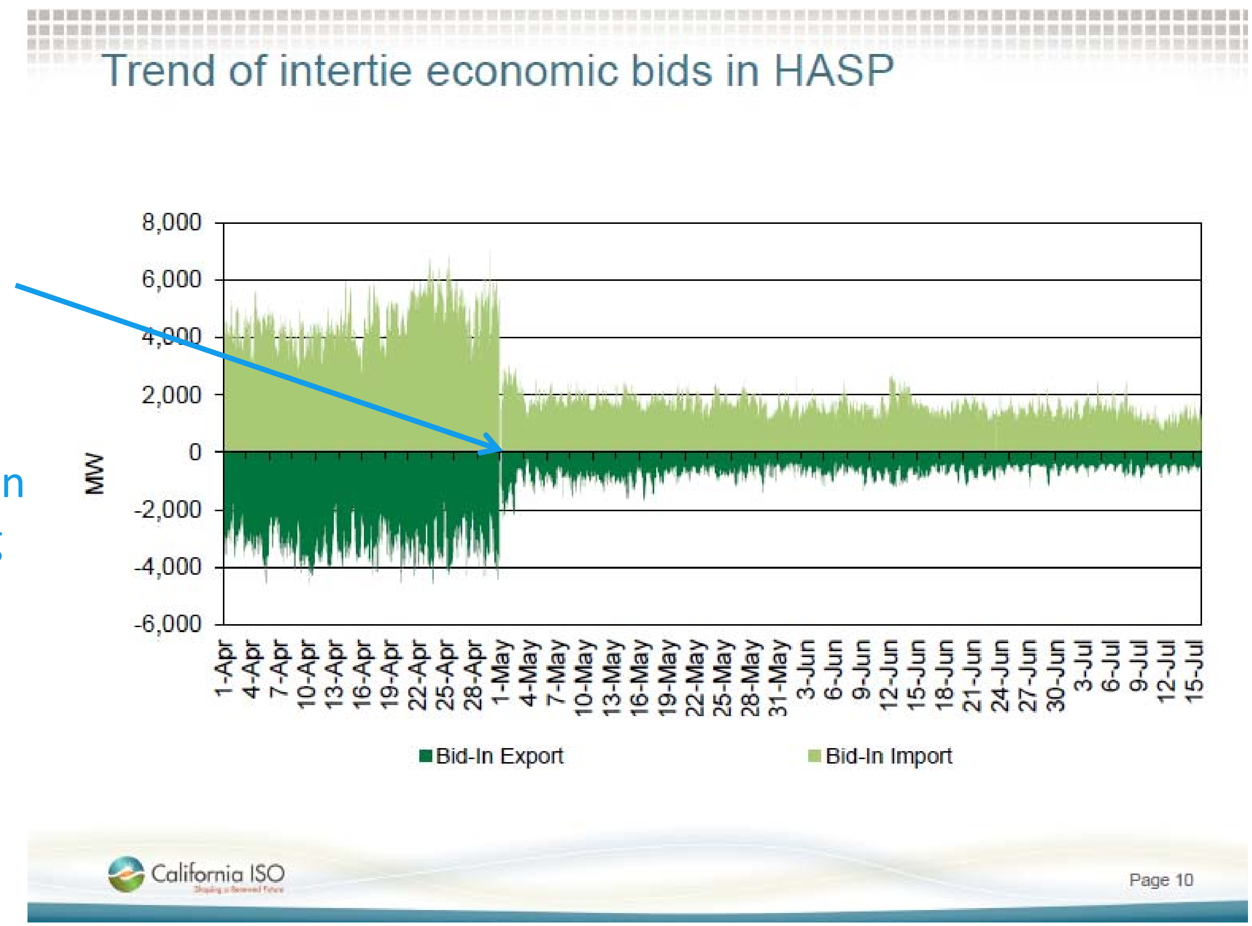
1. Governance
   - Conflicts of interests between PNW ratepayers and CA stakeholders
   - Goes beyond formal governance model – software, processes, staff decision making
2. Resource sufficiency
   - Design permits insufficient procurement of flexible reserves
   - Permits “leaning” on flexible generation assets in neighbouring BAAs
   - Increases reliability risk
   - Denies equitable compensation for flexibility
3. Free export (and wheel-through) transmission service
   - Shifts fixed costs of transmission onto load in exporting BAA
4. Pre-mature expiration of the value of OATT rights prior to EIM timeframe each hour
   - Confiscates congestion value of transmission investments to “make way” for EIM
5. VER integration costs shifted onto local load
   - Cost for committing flexible generation capacity not currently allocated to VERs
6. Market Monitoring/Price Mitigation
   - Department of Market Monitoring is a division of CAISO
   - Automatic mitigation can over-ride offer prices and dispatch units anyway

DETAILS OF MARKET DESIGN ARE IMPORTANT

Recent example of how market design impacts real-time markets

Source: http://www.caiso.com/Documents/MarketPerformanceandPlanningForumJul29_2014.pdf

May 1, 2014 - Launch of Fifteen Minute Market & HASP modified to have indicative pricing, rather than financially binding prices.



CAISO EIM AND THE NW

Concerns have been expressed with regard to governance issues and design choices of the CAISO EIM.

However, *status quo* is <u>not</u> an option for the Northwest

- CAISO EIM approach will affect the NW
  - Intra-hour markets affect the valuation and use of resources across all time frames, including resources not directly participating in that market
  - Fear that if no actions are taken, Pacific NW markets will be increasingly designed, operated and governed by CAISO

Desire to create a solution designed and governed by the NW in order to protect NW ratepayer's interests

NWPP MARKET COORDINATION INITIATIVE

- Designed and developed from ground up with the collaborative participation of 19 entities in the Northwest, including BC Hydro
- Governed by the interests of the Northwest region: hydroelectric generation, transmission rights under OATT framework

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FUNDING ORGANIZATIONS

- Avista Corporation
- Balancing Authority of Northern California (BANC)
- BPA
- BC Hydro/Powerex
- Eugene Water & Electric Board
- Idaho Power Company
- NaturEner
- NorthWestern Energy
- Puget Sound Energy
- Chelan County PUD
- PacifCorp*
- Portland General Electric
- Clark County PUD*
- Grant County PUD*
- Snohomish County PUD
- Seattle City Light
- Tacoma Power
- Turlock Irrigation District
- WAPA, Upper Great Plains

* Organizations providing funding up to Phase 3

NWPP MC OPPORTUNITIES – BIG PICTURE

- Coordinate operations while retaining local control and responsibility at the Balancing Authority level
- Share critical transmission system information while retaining individual transmission provider duties
- Capture diversity benefits through improved regional forecasting and intra-hour re-dispatch of units
- Enhance reliability through wide-area visibility
- Focus Market Operator on low-cost, high-value, straightforward functions while minimizing regulatory changes

VISION FOR A NW SCED

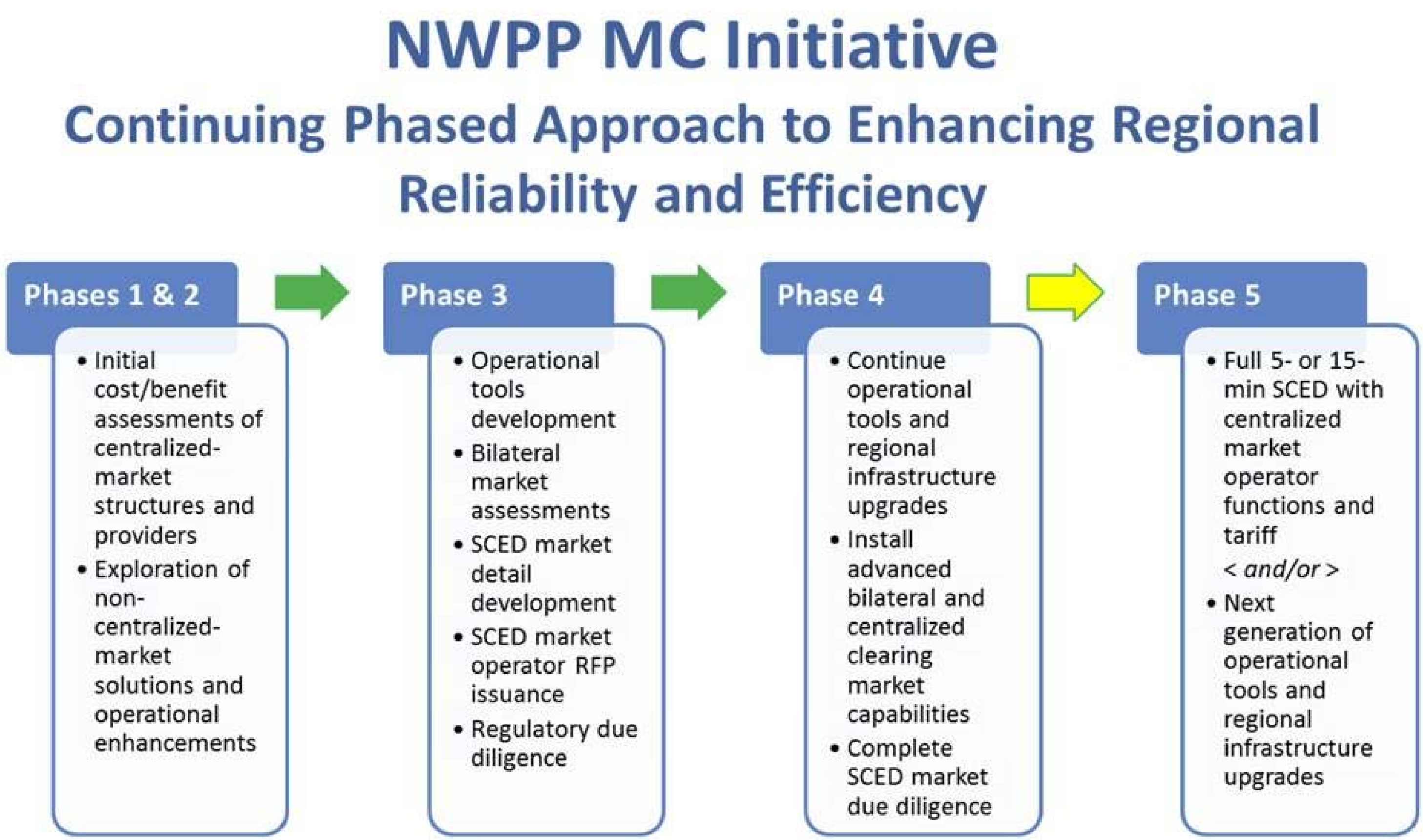
SCED is…

- A within-hour energy only market
- Security-constrained via state estimator model
- Market to optimize energy dispatch
- Centralized unit dispatch for offered resources
- Uses “as available” transmission system capability

SCED is <u>not</u>…

- An RTO (with planning, day-ahead markets, etc)
- Capacity market
- A replacement for current bi-lateral contractual business structure
- A provider of transmission services

NWPP MC INITIATIVE – CURRENT STATUS



Starts April 1, 2015

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OVERVIEW OF OPERATIONS PLANNING MODELS AT BC HYDRO

ALAA ABDALLA & ZIAD SHAWWASH

GRM GRM/UBC

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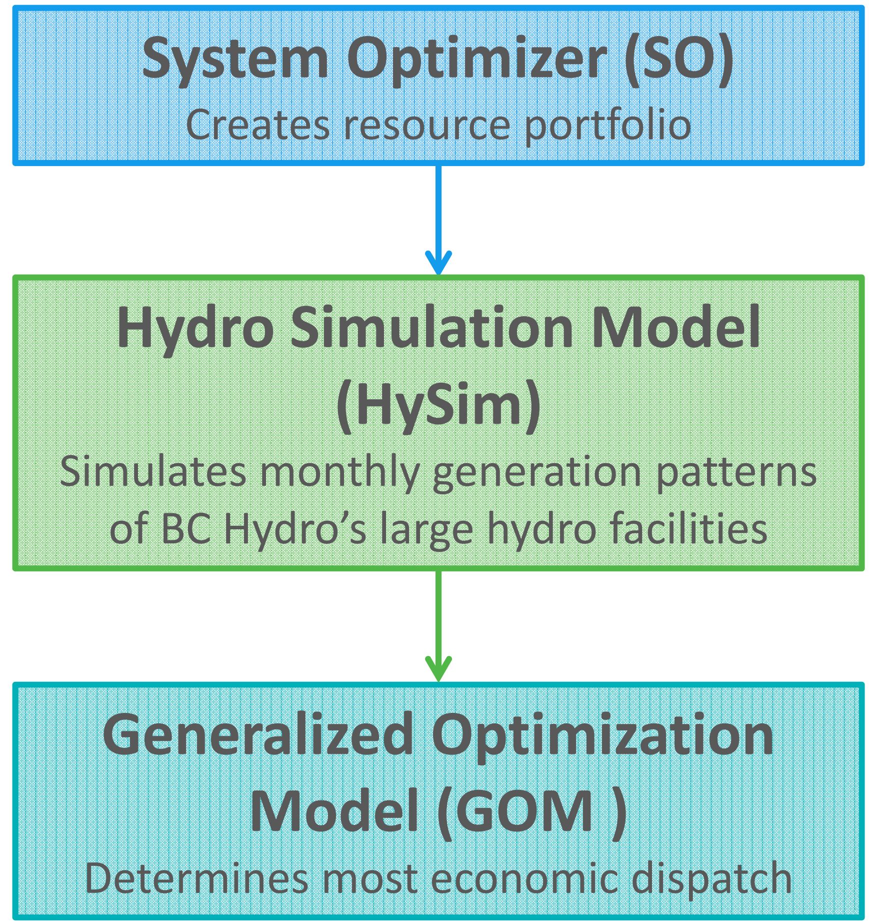
STUDY INVOLVES 3 OPERATIONS PLANNING MODELS

Follows GRM's typical modeling procedure used for operations, benefits and planning studies

- Water Use Plans
- Columbia River Treaty
- New and/or project upgrades (e.g. Site C, Resource Smart projects)
  - Environmental impacts
  - Optimization of plant/turbine/unit characteristics
  - Trading and other benefits
- Optimize planned/unplanned outage frequency/timing
- Pumped storage
- Wind integration



SYSTEM OPTIMIZER (SO)

- Mixed integer programming optimization model developed by Ventex
- Creates optimal generation and transmission resource expansion sequence given a set of input assumptions and constraints
- Inputs
  - Load forecast, Demand-Side Management savings, natural gas/electricity prices, available resource options
- Constraints
  - Transmission limits, annual hydro generation profile
- Used by Resource Planning for integrated resource planning

HYDRO SIMULATION MODEL (HYSIM)

- Developed in-house
- Monthly simulation model of BCH generation system with no foresight
- Includes detailed hydraulic modelling of system, including Columbia River Treaty operating rules
- Uses iteration method to determine most economic dispatch of generating system subject to fixed operating constraints
- Models across 60 years of historical inflows
- Market opportunities included with both heavy and light load prices (import & export) and tie-line limitations

GENERALIZED OPTIMIZATION MODEL (GOM)

- Developed in-house
- Linear deterministic model determines most economic dispatch of generating system subject to:
  - Operating constraints (operating and flow constraints, unit efficiency curves, forebay and tailrace elevations, etc.)
  - Intertie limits
  - Historical inflows
  - Reservoir storage targets from HySim simulation to limit model foresight (month and year end targets for GMS, MCA, ARD)
  - Variable time and sub-time step (hourly, daily, weekly and monthly with sub-time-step (PLH, HLH, SLH & LLH).
- Typically run 1 year at a time

GOM – OBJECTIVE FUNCTION

- Objective function is to maximize the value of BC Hydro resources
- Trade-off between present benefit/revenue with potential long-term value of resources
- Decisions:
  - When and how much energy to import/export?
  - Where and how much water to store or draft while meeting the firm domestic load and system constraints?

Maximize

∑ Spot sales in US * US Price + ∑ Spot sales in AB *AB Price
- ∑ Thermal Cost
+ ∑ (End Storage-End Target) * Marginal value of water
+ ∑ Surplus Capacity * Ancillary Service Prices

DECISION VARIABLES IN GOM

- Non-hydro variables: import and export, thermal
  - Decision: when and how much to import/export?
    - Information needed – market information (import/export prices and tie limits)
- Hydro variables
  - Turbine and spill releases
  - Power generation
  - Additional decision: store or draft? When, where and how much?
    - Information needed: marginal cost of water and operation target for each reservoir

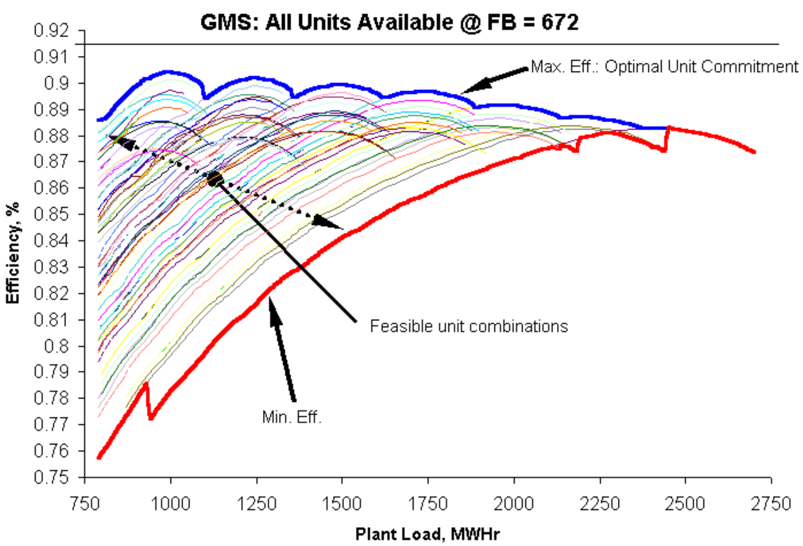
MODEL CONSTRAINTS IN GOM

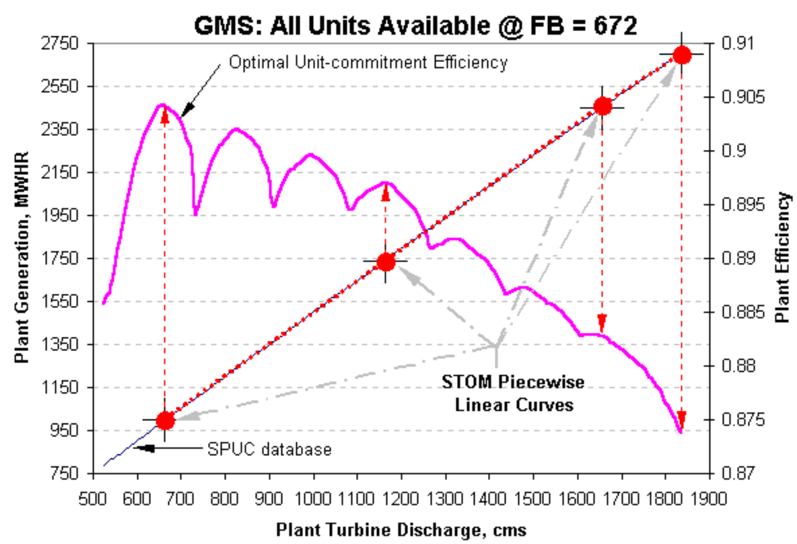
- Hydro Constraints
  - Forced spill discharges from a reservoir (represented by piecewise linear function)
  - Turbine & spill discharges from a reservoir
  - Upstream turbine & spill inflows to a reservoir
  - Upper and lower bounds on turbine & spill discharges from a reservoirs
    - includes non-power requirement (e.g., fish & environmental flows)
  - Upper & lower bounds for total plant discharge from a reservoir
  - Mass-balance (continuity) equation for reservoirs
  - Upper & lower bounds for reservoir storage and ramping up/down of storage
  - Turbine discharge ramp rates (increment/decrement)
- Power Generation Constraints
  - Piecewise linear generation production with variable head
  - Upper & lower plant generation bounds
  - Plant ramp rates (increment/decrement)
- System Constraints
  - Load-resource balance
  - Real-time operational contingency, regulating, following and imbalance reserves
  - Max/min limits on tie line available transfer capability to markets in U.S. and Alberta

MODELING HYDRO POWER GENERATION

Assume optimal unit commitment and loading

- Modeled using piecewise linear curves
- Advantage of using piecewise linear curves in linear programming is that plants are loaded at maximum efficiency points

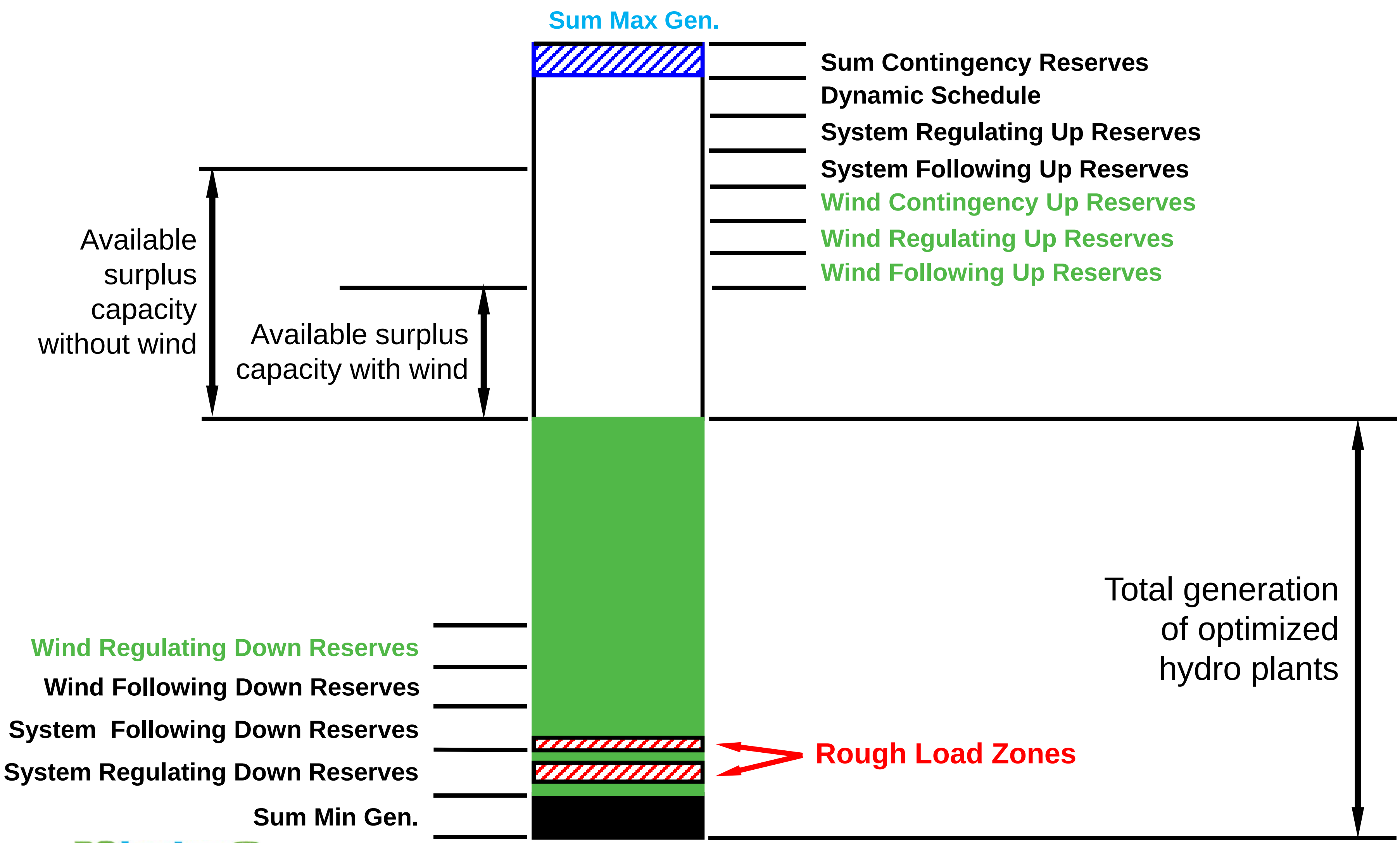




MODELING CAPACITY RESERVES IN GOM

- Contingency reserves
  - 3% load + 3% system generation
- Regulating up/down reserves for wind and load
- Following up/down reserves for wind and load
- Imbalance up/down reserves for wind and load
  - Includes forecasting error for load and wind (imbalance)
- Dynamic schedule contracts will be treated as Regulating Up reserves

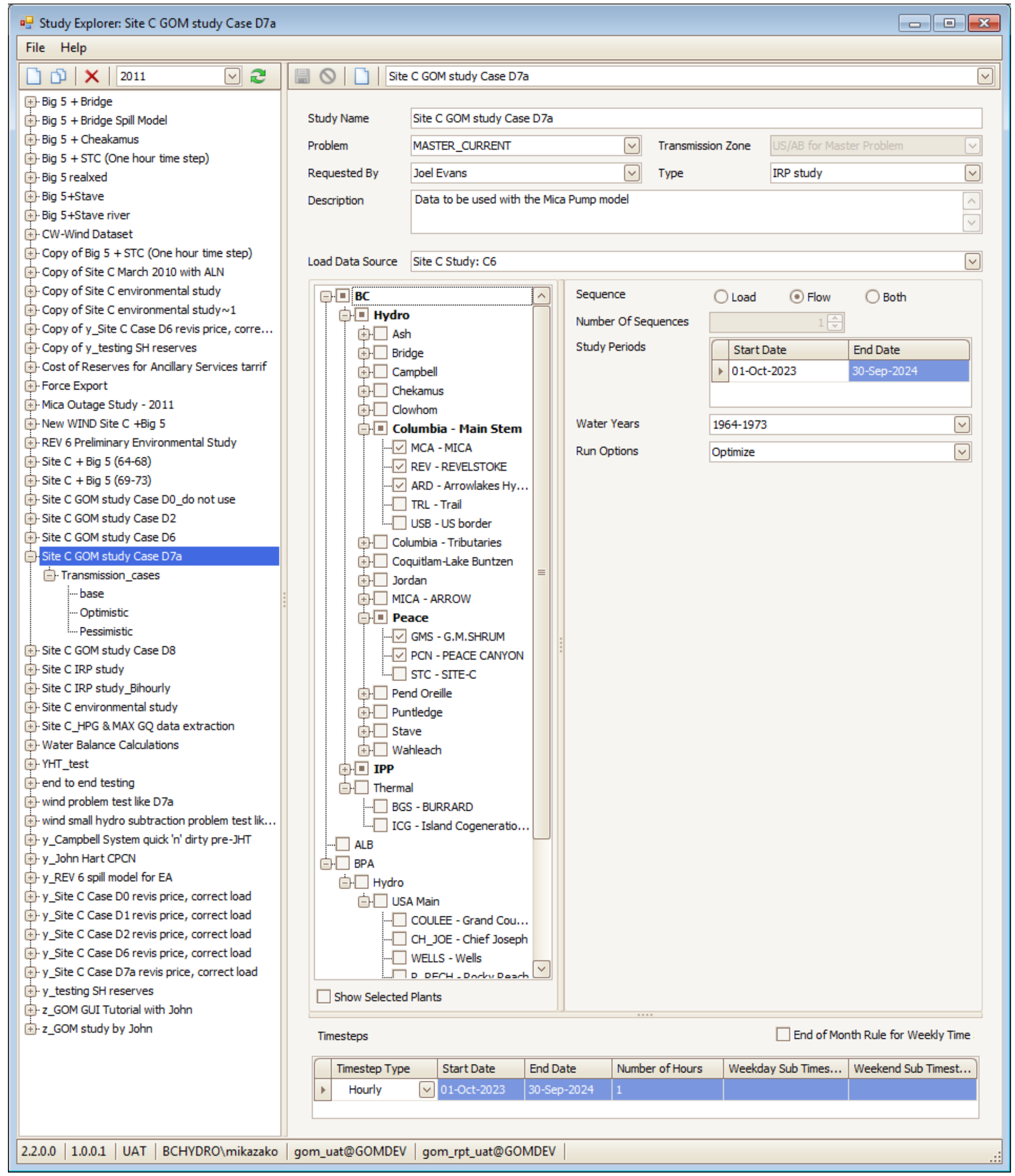
MODELING SYSTEM RESERVES IN GOM



GOM GUI

Easy-to-use **Study Interface**

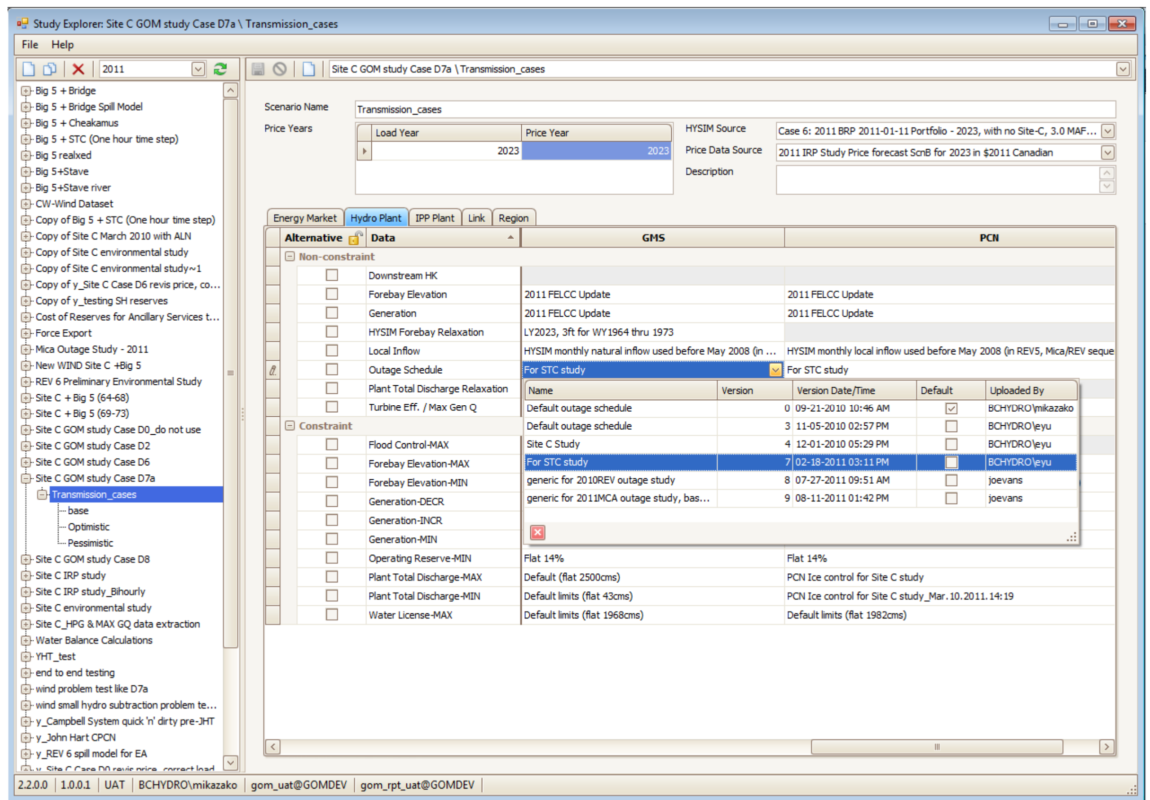
- Define optimization problem
  - Standard/ w/wo Wind, Regional (TX), CRT …
- Select plants optimized
  - Hydro, Thermal, IPPs
- Select study type
- Select study sequence
  - Flow, load or both
- Select run option
  - Simulate, optimize or both



GOM GUI

Easy-to-use **Scenario GUI**

- Define study input data based on: load year, price year, sources of data
- Define study scenarios:
    - Energy (e.g. prices)
    - Hydro limits (e.g. outages)
    - IPP plant limits
    - Transmission limits
    - Regional limits



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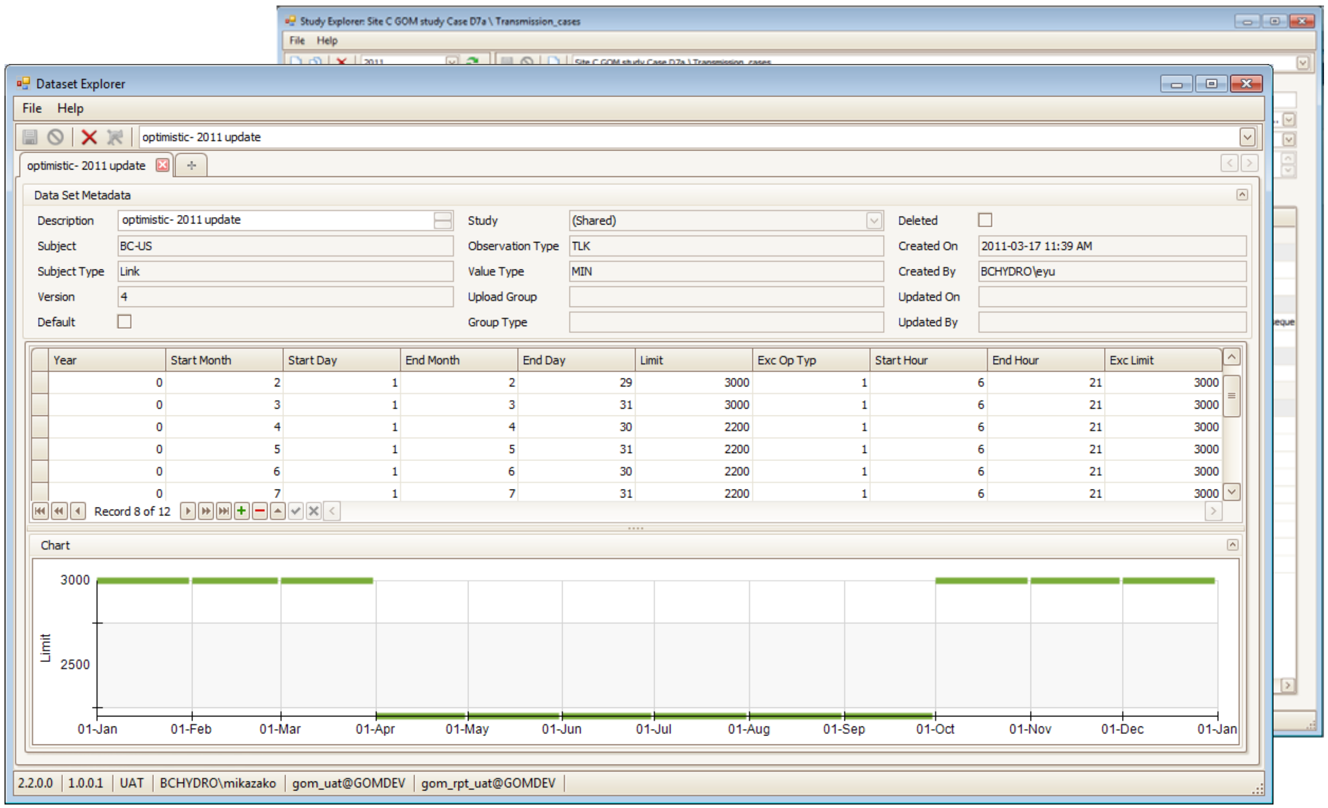
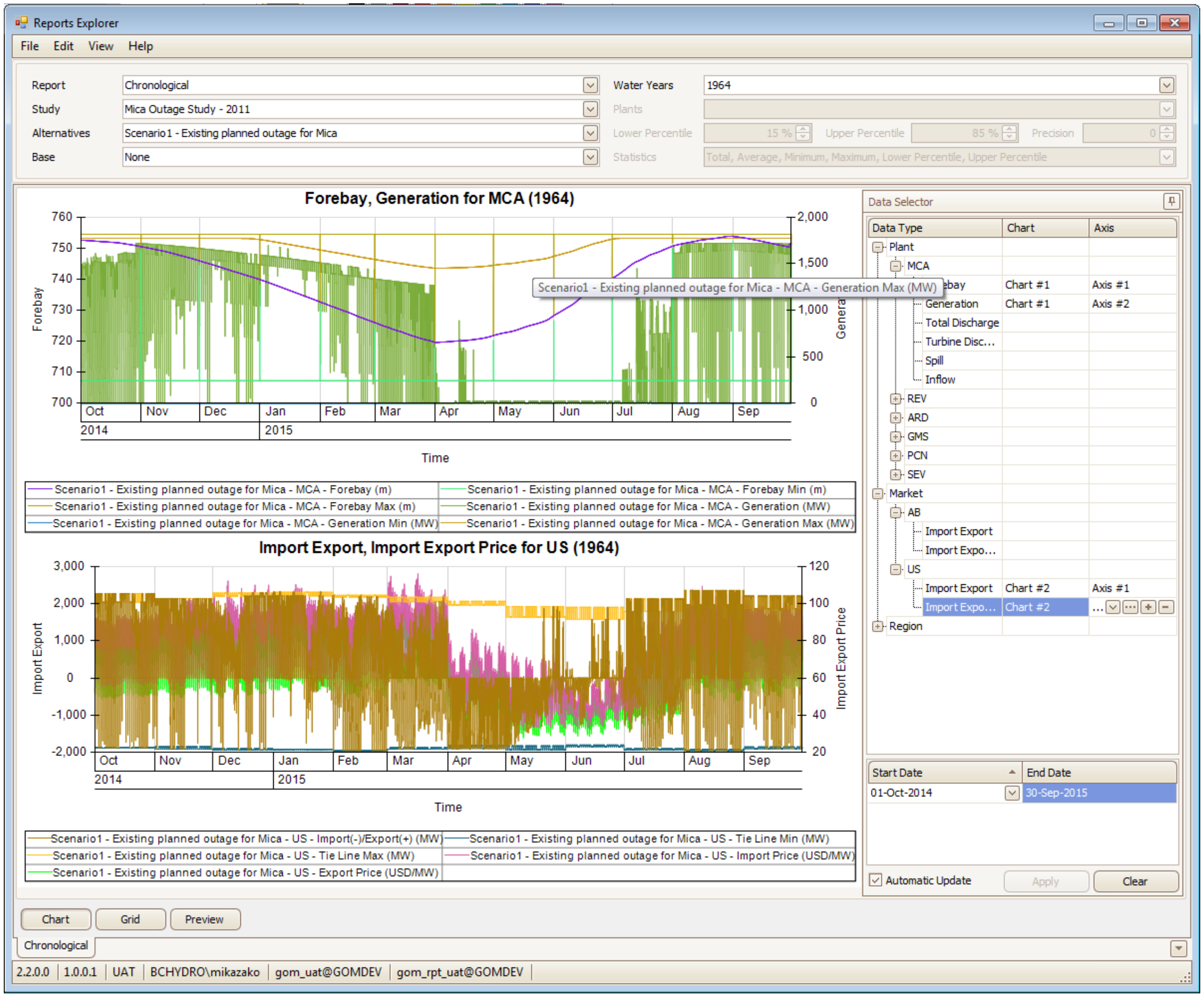
GOM GUI

Easy-to-use **Alternative GUI**

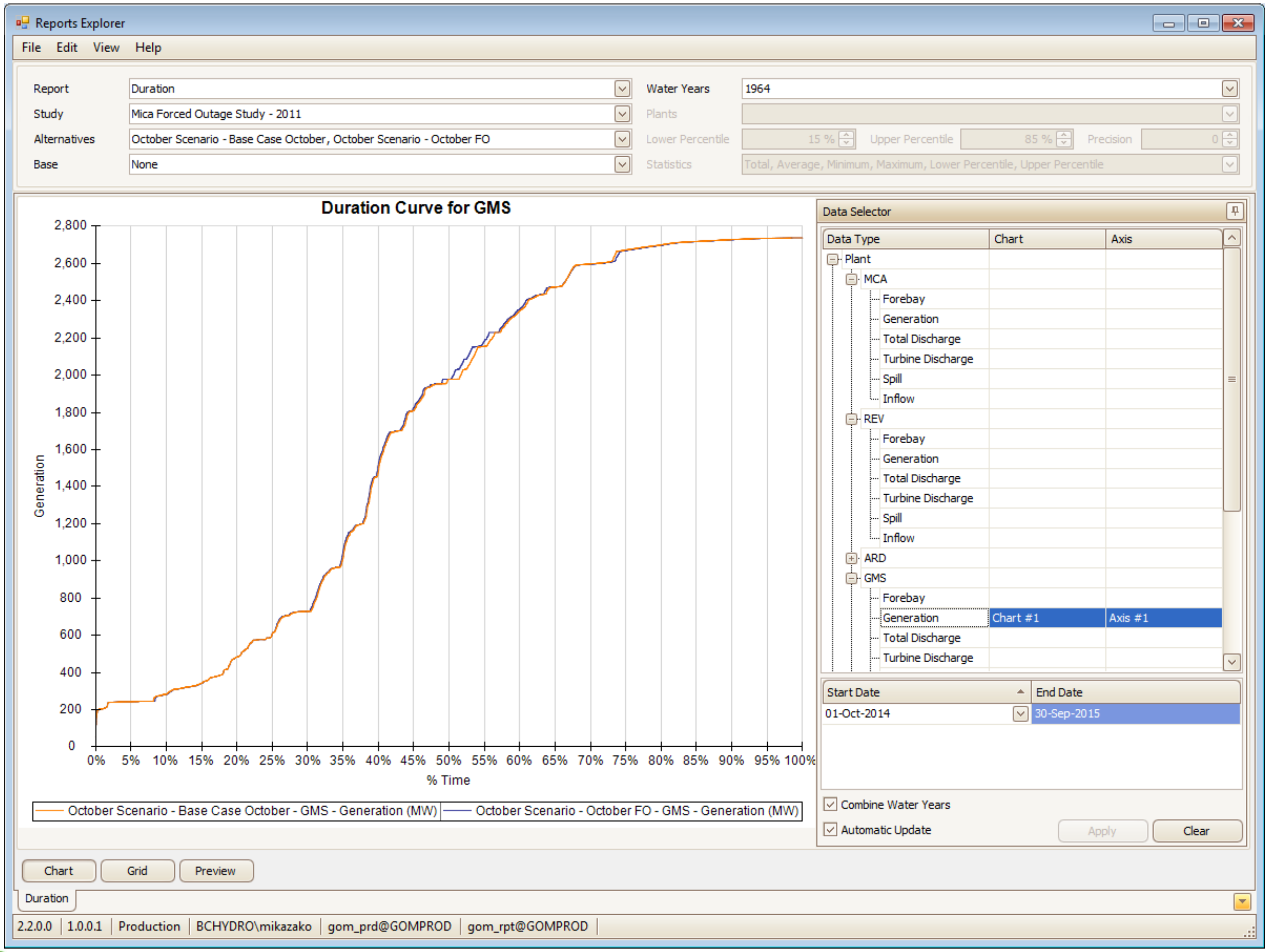
- Specify limits on selected scenarios (e.g. US intertie limits)



EXAMPLE GOM OUTPUT – OPTIMIZED FOREBAY, GENERATION, IMPORT/EXPORT



EXAMPLE GOM OUTPUT – GENERATION DURATION CURVES



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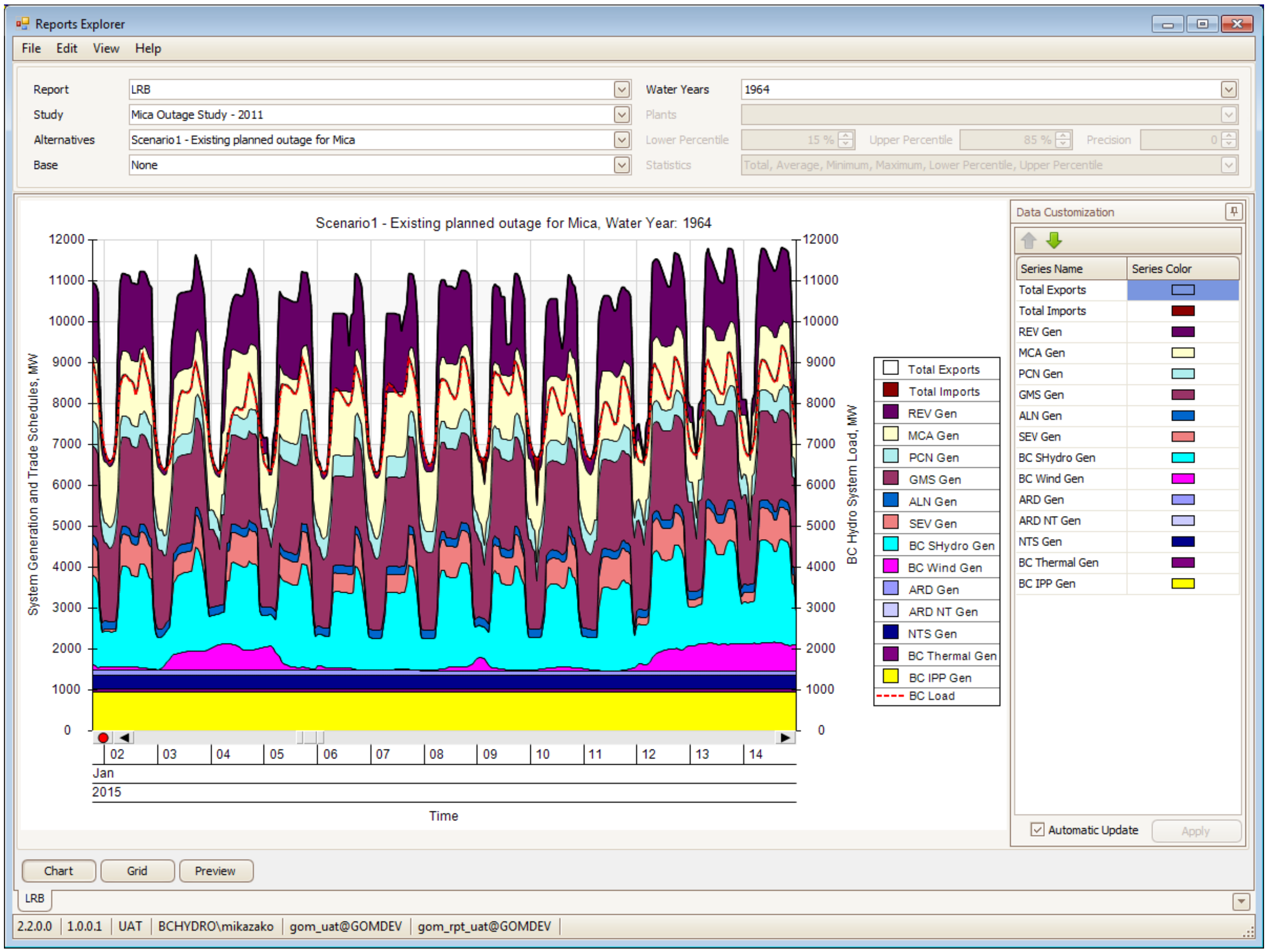
EXAMPLE GOM OUTPUT – LOAD-RESOURCE BALANCE



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STUDY METHODOLOGY

TWO COMPONENTS TO BC HYDRO WIND INTEGRATION STUDY

- **Within-Hour Reserves** – Incremental capacity required for regulation, load following and imbalance and associated cost.
- **Day-Ahead Opportunity Cost** – Impacts of the day-ahead wind forecast error on availability of system flexibility and resulting impacts to trade in the day-ahead power markets.

PART 1:
CAPACITY RESERVE REQUIREMENTS AND COSTS

BRUCE HENRY

BCH CONSULTING

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WITHIN-HOUR RESERVES

Description of the Impact

- The intermittent nature of wind power production output can increase the level of reserve capacity needed to maintain electric system performance
- The amount of additional reserve capacity that is attributed to wind is over and above all other load and generation contingency and operating reserve requirements

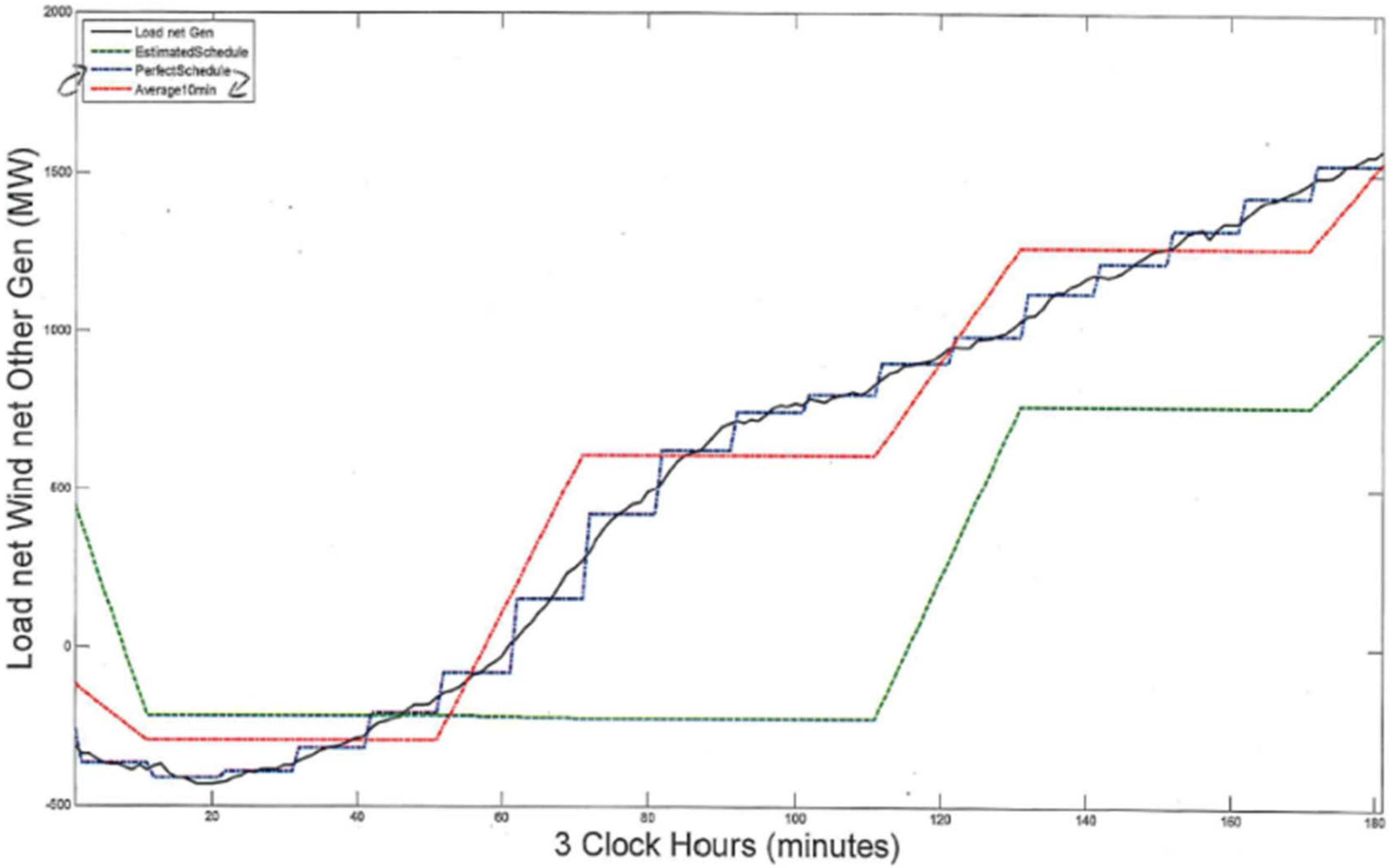
WITHIN-HOUR RESERVES

Definitions

- Hourly Market (Status Quo)
  - Regulation – 10 minute average less one minute
  - Load Following – Perfect hourly forecast less 10 minute average (10 minute before/after hour ramps)
    - Used 60 minute rolling average instead of 10 minute average in last study
  - Imbalance – Hourly forecast schedule less perfect hourly forecast (10 minute before/after hour ramps)

  - 10-min load following time period used in:
    - Eastern Wind Integration and Transmission Study
    - Portland General Electric Wind Integration Study Phase 4
    - Pacificorp 2012 Wind Integration Resource Study
    - BPA Power-14 Initial Rate Proposal

WITHIN-HOUR RESERVES



WITHIN-HOUR RESERVES

Definition

- 15-Min Market (Sensitivity Test)
  - Regulation – 10 minute average less one minute
  - Load Following – Perfect 15-min forecast less 10 minute average (before/after 15-min period ramps TBD)
  - Imbalance – 15-min forecast schedule less perfect 15-min forecast (before/after 15-min period ramps TBD)

WITHIN-HOUR RESERVE CALCULATIONS

Methodology

- Calculate reserve requirements for each type of reserve for load only and wind only using 1minute data over a 10 year period.
- Bin data by month
- Determine monthly reserve block to cover 3 standard deviations in each month
- Combined monthly load and wind reserve blocks using root sum squared methodology
- Subtract load reserves from combined load and wind reserves to determine incremental wind reserves
- Load minus wind methodology?
- Dynamic reserve calculation methodology?

WITHIN-HOUR RESERVES

Methodology (Continued)

- Include incremental reserve requirements in GOM and determine opportunity cost of holding incremental reserves based on CAISO Ancillary Services market prices as a proxy for the values of reserves as there is no liquid capacity market in the PNW.
  - Regulation – CAISO up-regulating & down-regulating prices
  - Load Following & Imbalance – CAISO spinning ancillary services prices
- Prices for 15-minute market sensitivity case?
- No opportunity cost of reserves if there are system constraints

WITHIN-HOUR RESERVES

Methodology (Continued)

- Modeling assumes incremental reserves are provided by BC Hydro system - Mica (4 units-1800MW), Revelstoke (5 units-2505MW), GMS (10 units-2730MW) , Peace Canyon (4 units-700MW), and Arrow Lakes (2 units-192.4MW) provide reserve capacity for load and wind. Latter two only following and contingency reserves.
- Assumed Alberta energy prices were the same as the U.S.
- Only transmission constraints were the tie to the U.S. and to Alberta

WITHIN-HOUR RESERVES

Case	Description
1	Base case with no wind energy, reserves for load only
2	Heavy load hour and light load hour blocks of energy, equivalent in daily volume to the energy that simulated wind produces, are added to represent the idea generator with no variability of uncertainty.
3	Wind energy replaces the blocks of energy but reserves for wind are not yet incorporated.
4	Incremental operating reserves are blocked from the generation resource stack to accommodate incremental reserve requirements for wind

Variability Cost = Case 3 – Case 2
Wind Reserves Cost = Case 4 – Case 3

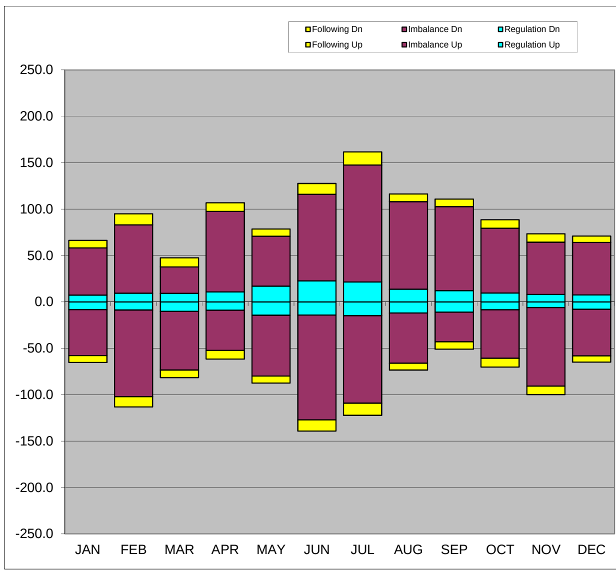
WITHIN-HOUR RESERVES

Sample from previous study – 15% CAPEX Scenario

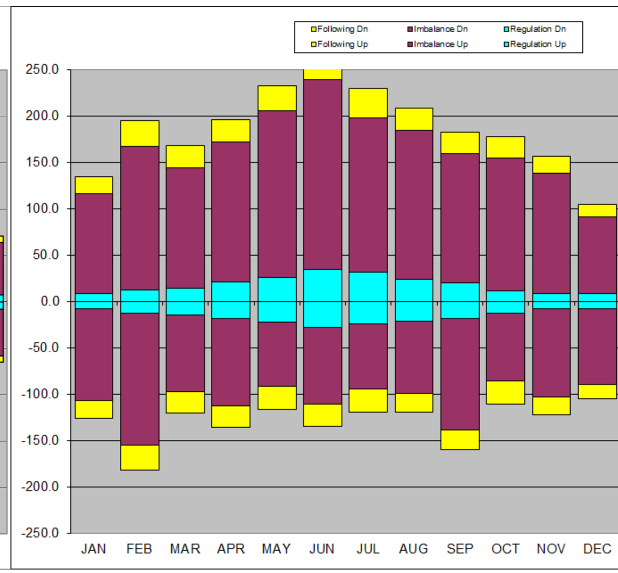
Incremental Wind Full Time.

WITHIN-HOUR RESERVES

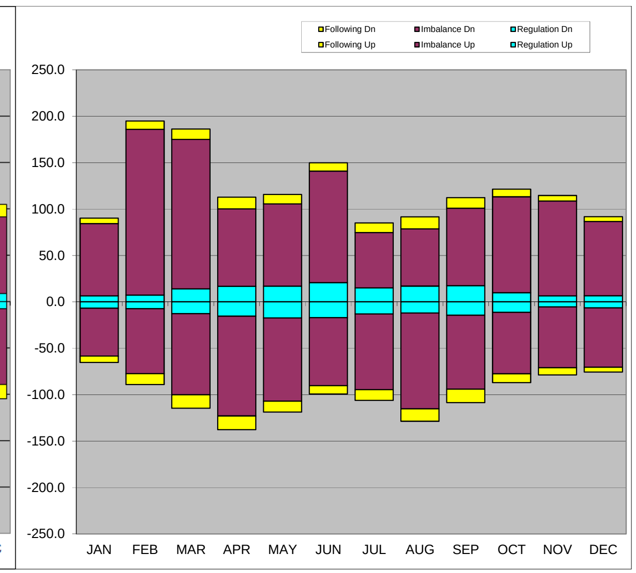
Sample from previous study – 15% CAPEX Scenario



Ramp Down
10pm-2am



Normal



Ramp Up
6am to 10am
4pm to 8pm

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PART 2: DAY-AHEAD OPPORTUNITY COSTS

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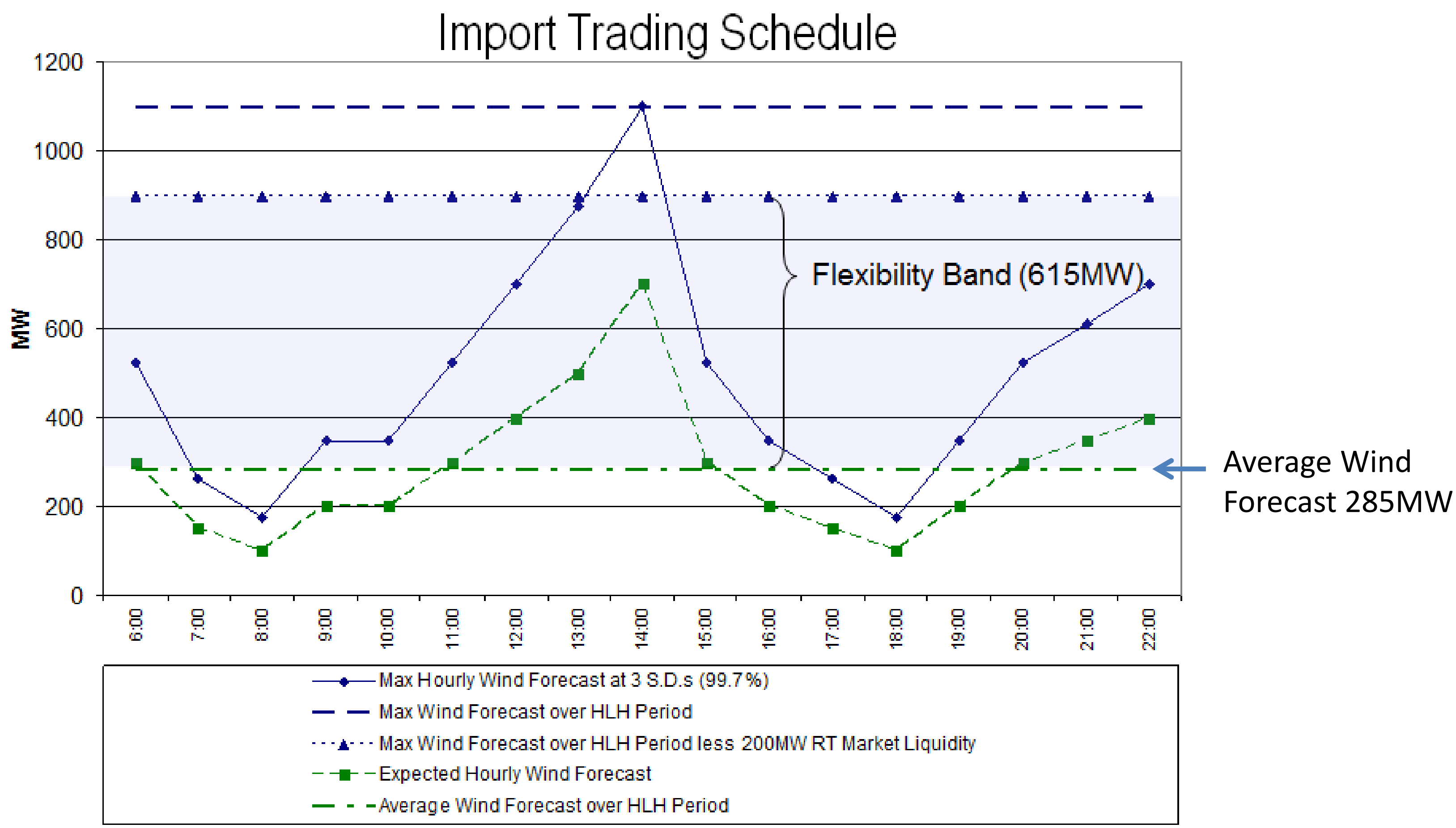
DAY AHEAD OPPORTUNITY COSTS

Description of Impact

- BC Hydro trades energy via Powerex in two markets:
  - **Day-Ahead (DA) Market**: Energy is traded Monday through Saturday as two blocks of energy: a light-load hour (LLH) block for hour-ending 1 to 6 and 23 to 24, and a high-load hour (HLH) block for hour-ending 7 to 22. Sunday trades as a 24-hour LLH block. The DA market makes up most of energy trading volume.
  - **Real-Time (RT) Market**: Energy is traded in hourly blocks everyday up to 20 minutes before the hour. The RT market is relatively shallow. Buyers and sellers can experience price impacts associated with the lack of market liquidity. The RT market is only about 200MW deep before liquidity premiums and/or hard limits are reached.
- Powerex will only commit to DA market with a very high level of certainty
- Powerex trades all available system flexibility up to constraints
- Due to the need for BC Hydro to manage the DA wind forecast error, a portion of BC Hydro's system flexibility must be reserved. ~200MW of RT market flexibility can be used to contribute to system flexibility as well.
- If this flexibility could have otherwise been used to exploit DA energy market opportunities, there is a **wind opportunity cost**

IMPORT TRADING EXAMPLE



WOC=(615MW*($40/MWh (rsys) - $10/MWh (Market Price)) *16hrs)/(285MW*16hrs) = $64.74/MWh

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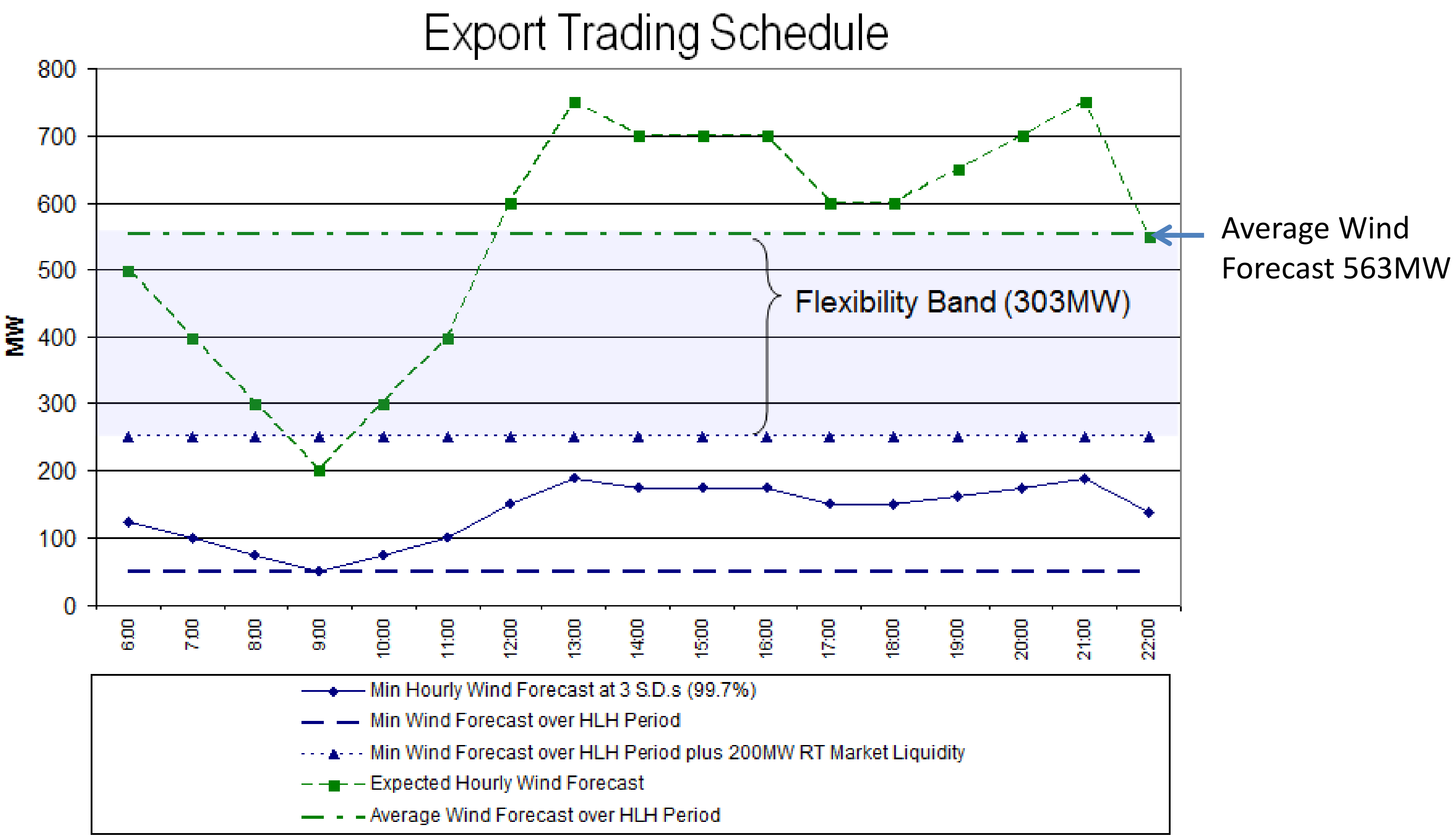
EXPORT TRADING SCHEDULE



WOC=(303MW*($60/MWh (Market Price)-$40/MWh (rsys)) *16hrs)/(563MW*16hrs) = $10.76/MWh

DAY AHEAD OPPORTUNITY COSTS

Methodology

- Use simulated NWP wind power forecasts prepared by 3Tier
- The level of system flexibility required to manage the day-ahead wind forecast error is determined at a 3 standard deviation confidence level.
- The opportunity cost of maintaining this flexibility is modeled in GOM
- Valued spilled water at rsys (BC Hydro’s mid-term value of energy) and curtailed wind at rsys+REC value
- If no transmission availability, then there is no opportunity cost

SCENARIOS AND INPUT DATA

MAGDALENA RUCKER

RESOURCE PLANNING

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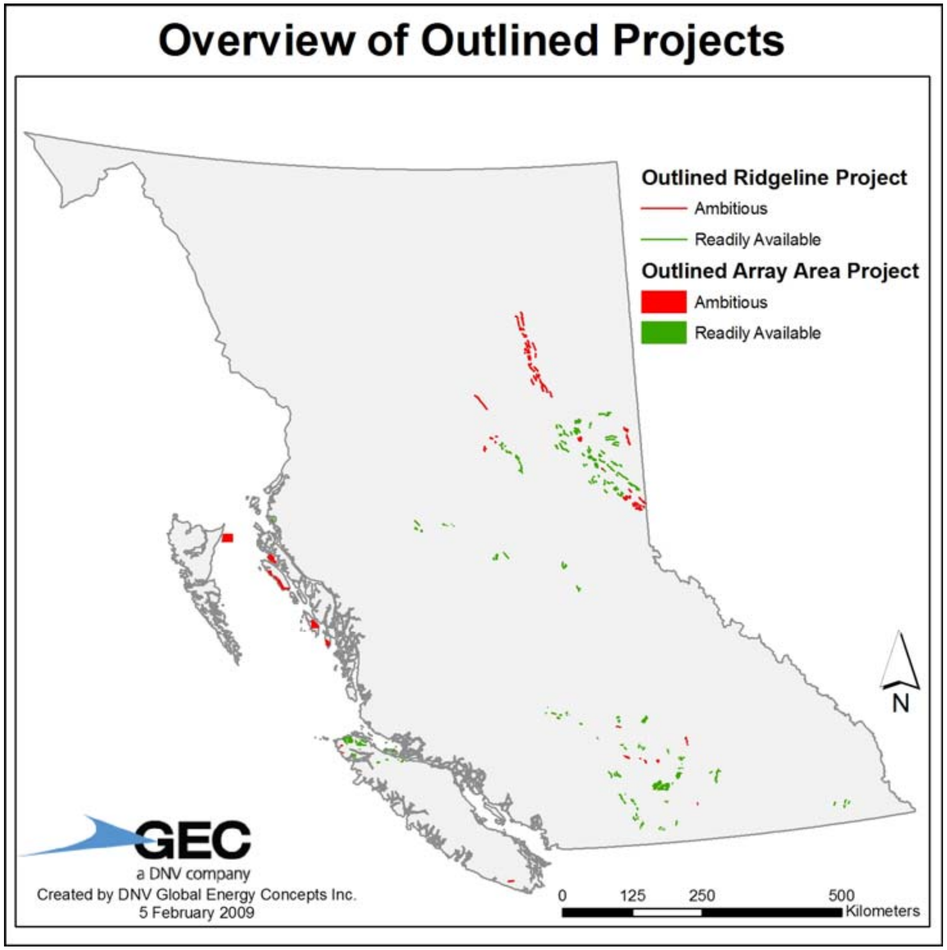
INPUT DATA

- Study will be based on 10 years of water, load and wind data
- Synchronized load and wind data for period Aug 1998 – Jul 2008
  - 1-minute load data based on historic actuals
  - Wind data based on updated 2009 BC Hydro Wind Data Study
- Water data based on historic actuals for period 1964 - 1973
  - Period considered representative of full 60-yr water record
  - May be able to synchronize water with load/wind if data becomes available in time for study

INPUT DATA - WIND

2009 BC Hydro Wind Data Study

- Used mesoscale modeling to create 10 years of 10-minute wind speed and wind power time series for 104 potential wind projects
- 3 years of simulated NWP wind speed/power forecasts for all projects



Wind power and forecasting time series being updated to reflect current turbine technology

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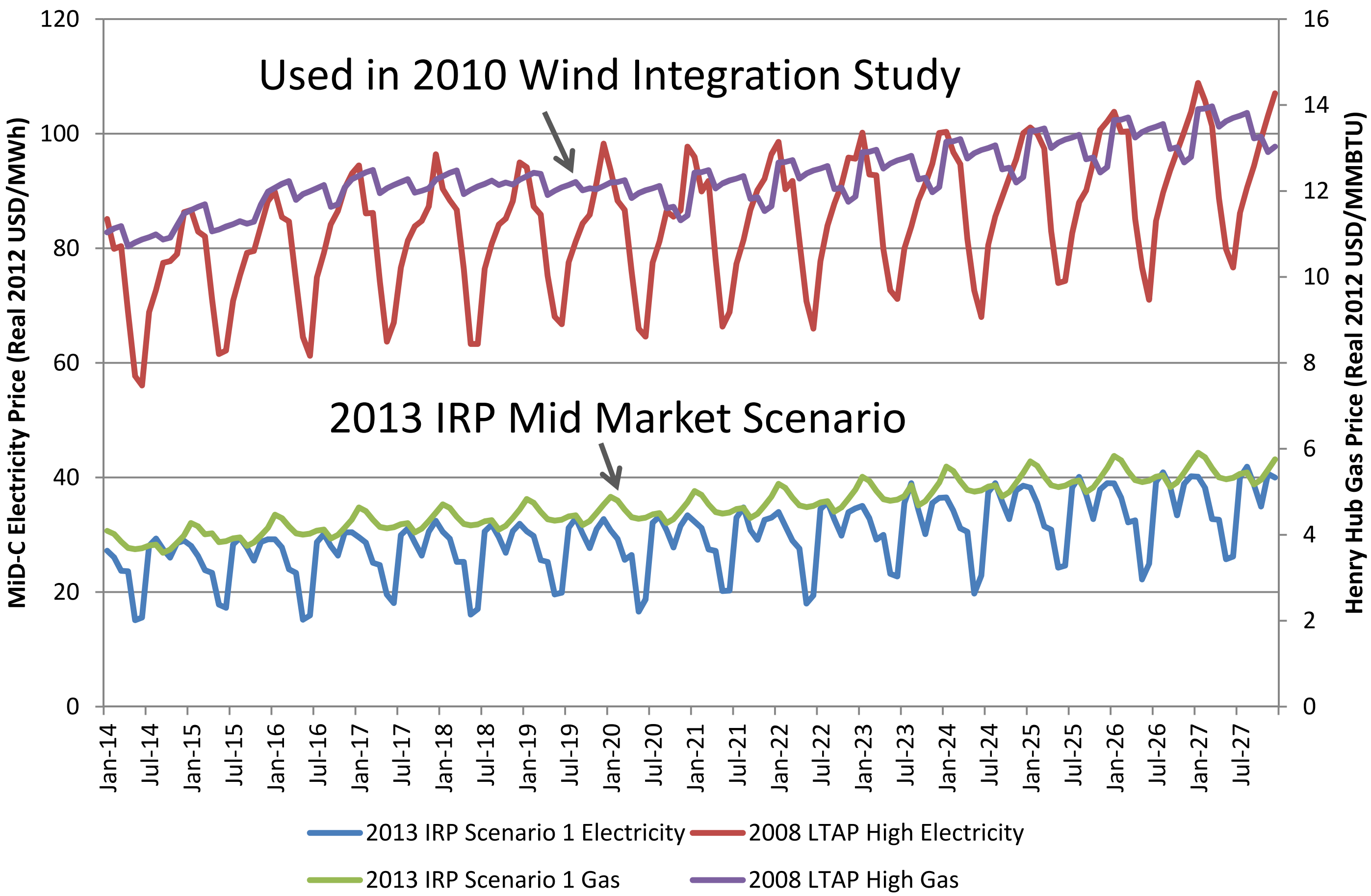
WIND DATA/FORECAST ERROR VERIFICATION

- Compare/verify simulated wind power characteristics with actual BC wind generation
  - Seasonal profiles, hourly variability, 10-min variability
- Compare/verify simulated day-ahead forecast error with operational forecast performance
  - Simplified interpretation of what is day-ahead

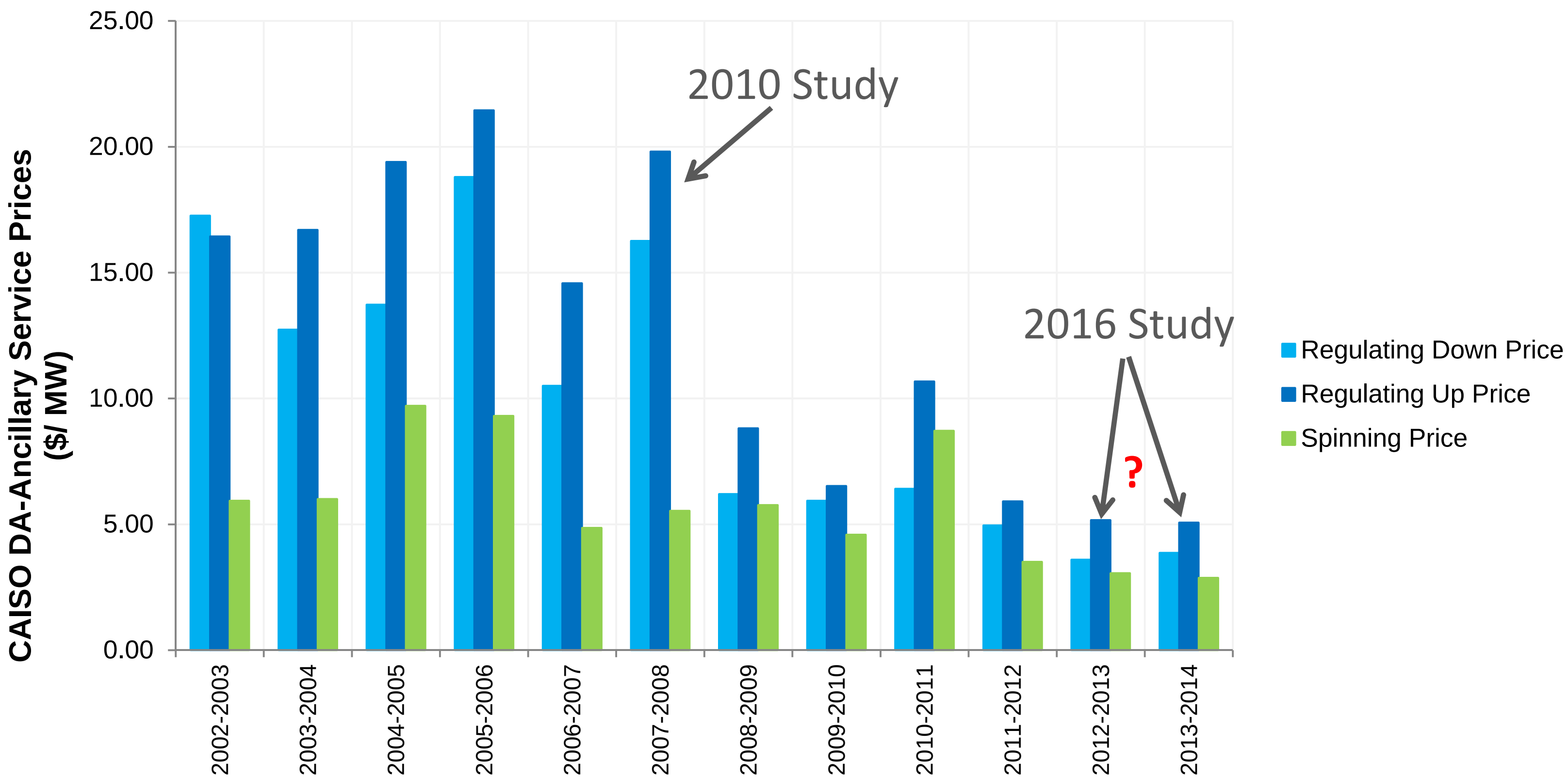
INPUT DATA – ENERGY MARKET PRICES



INPUT DATA – ENERGY MARKET PRICES AND REC

- Energy market prices
  - Guided by energy market price forecasts in 2013 IRP
  - Low Case = $20/MWh; Mid Case = $35/MWh; High Case = $50/MWh
- REC value
  - Based on 2013 IRP
  - REC = $4/MWh

INPUT DATA – ANCILLARY SERVICE PRICES



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INPUT DATA – TRANSMISSION LIMITS

- GOM models intertie constraints between BC and Alberta/US
- Intertie constraints provided on a monthly basis for HLH and LLH
- Transmission limits within BC are not modelled

SCENARIO CONSIDERATIONS

- Include resources committed to in 2013 IRP
  - Site C, REV6 and GMS upgrades
- Ensure load-resource balance in resource portfolio
- Model 2 wind penetration levels – 15% and 25% (TBD)
  - Wind farms selected based on cost → likely low wind diversity
- Model 3 market price scenarios
- Assume *status quo* market transactions (hourly)
- Sensitivity tests
  - High geographic diversification
  - 15-min market

PROPOSED SCENARIOS

Scenario	Type	Description/ Purpose	Parameters
1	Base	To determine wind integration cost for 15% wind penetration level for 3 market price scenarios	Penetration level – 15% Diversification – economic Market Price – low, mid, high Market transactions – status quo
2 (TBD)	Base	To determine wind integration cost for 25% wind penetration level for 3 market price scenarios	Penetration level – 25% Diversification – economic Market Price – low, mid, high Market transactions – status quo
3	Sensitivity	To test how geographic diversification impacts wind integration cost	Penetration level – 15% Diversification – high Market Price – mid Market transactions – status quo
4	Sensitivity	To test how a 15-min market would impact wind integration cost	Penetration level – 15% Diversification – economic Market Price – mid Market transactions – 15-min market

DISCUSSION / NEXT STEPS

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