Modeling V2G for a Utility with a High Wind Generation Portfolio

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SMUD
SACRAMENTO MUNICIPAL UTILITY DISTRICT
The Power To Do More.[SM]

College of Marine and Earth Studies
University of Delaware

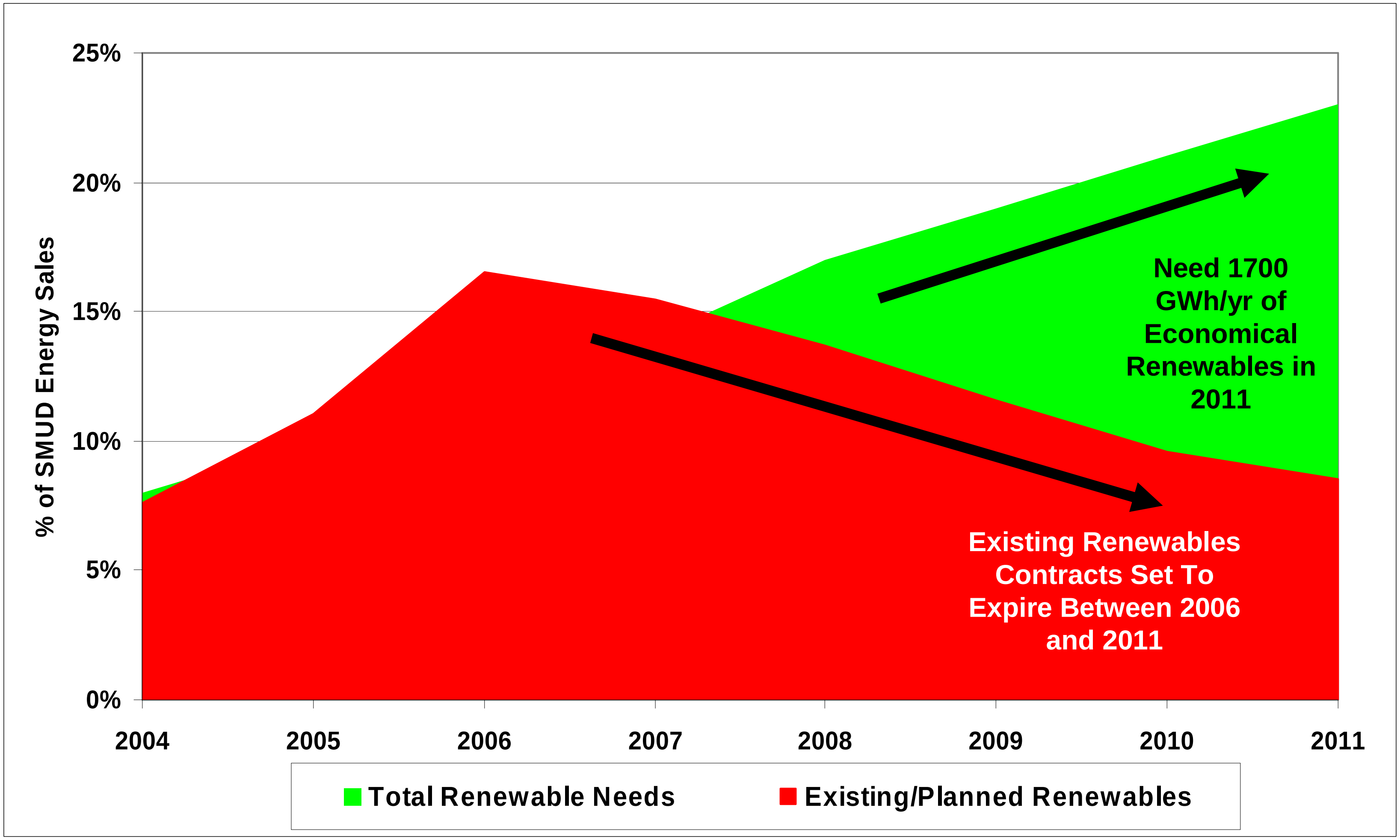
Sacramento Municipal Utility District (SMUD)

- 5th largest public power utility in the U.S.
- Serves 570,000 customers
- 12,000 GWh annual sales
- 3,300 MW system peak (5pm Summer)
- 750 MW minimum load (4am Spring)

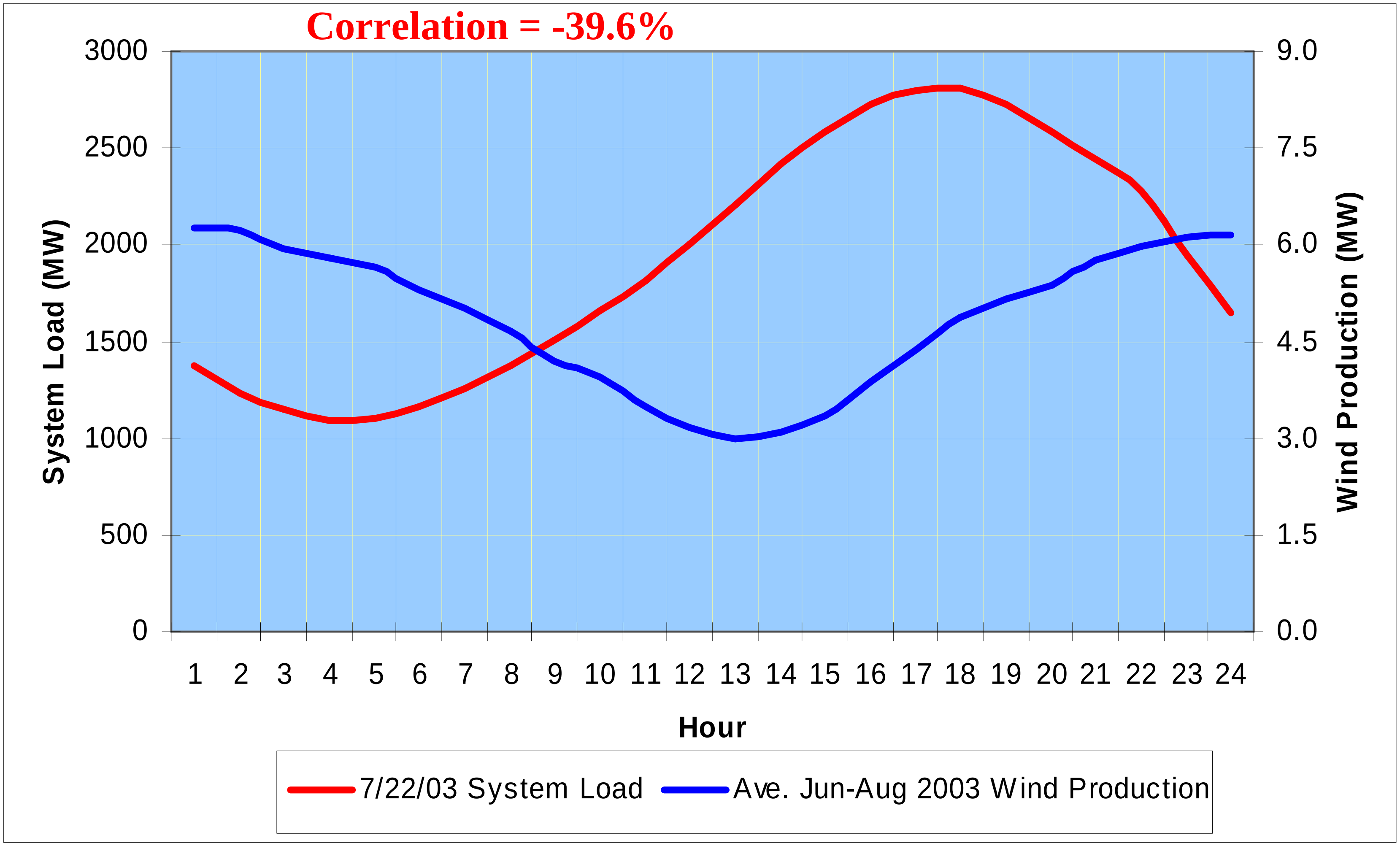
- 688 MW of conventional large hydro (15% of sales)
- 380 MW of local gas-fired cogeneration
- 39 MW of wind; 10 MW of PV
- Expect 200+MW of wind by 2011 at Solano

SMUD's Renewable Portfolio Goals

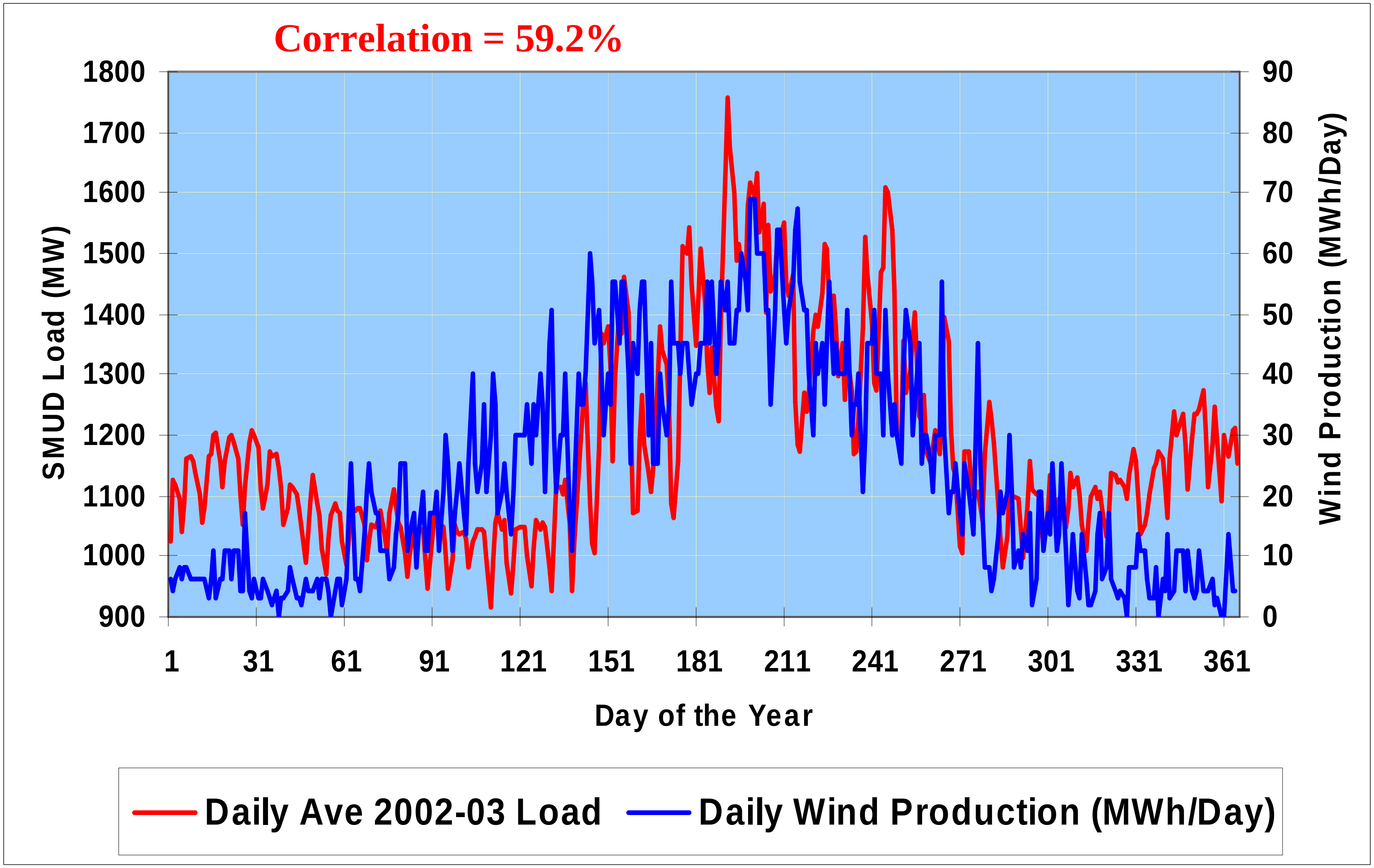
(2011 Goal: 20% for RPS & 3% for Green Pricing Program)

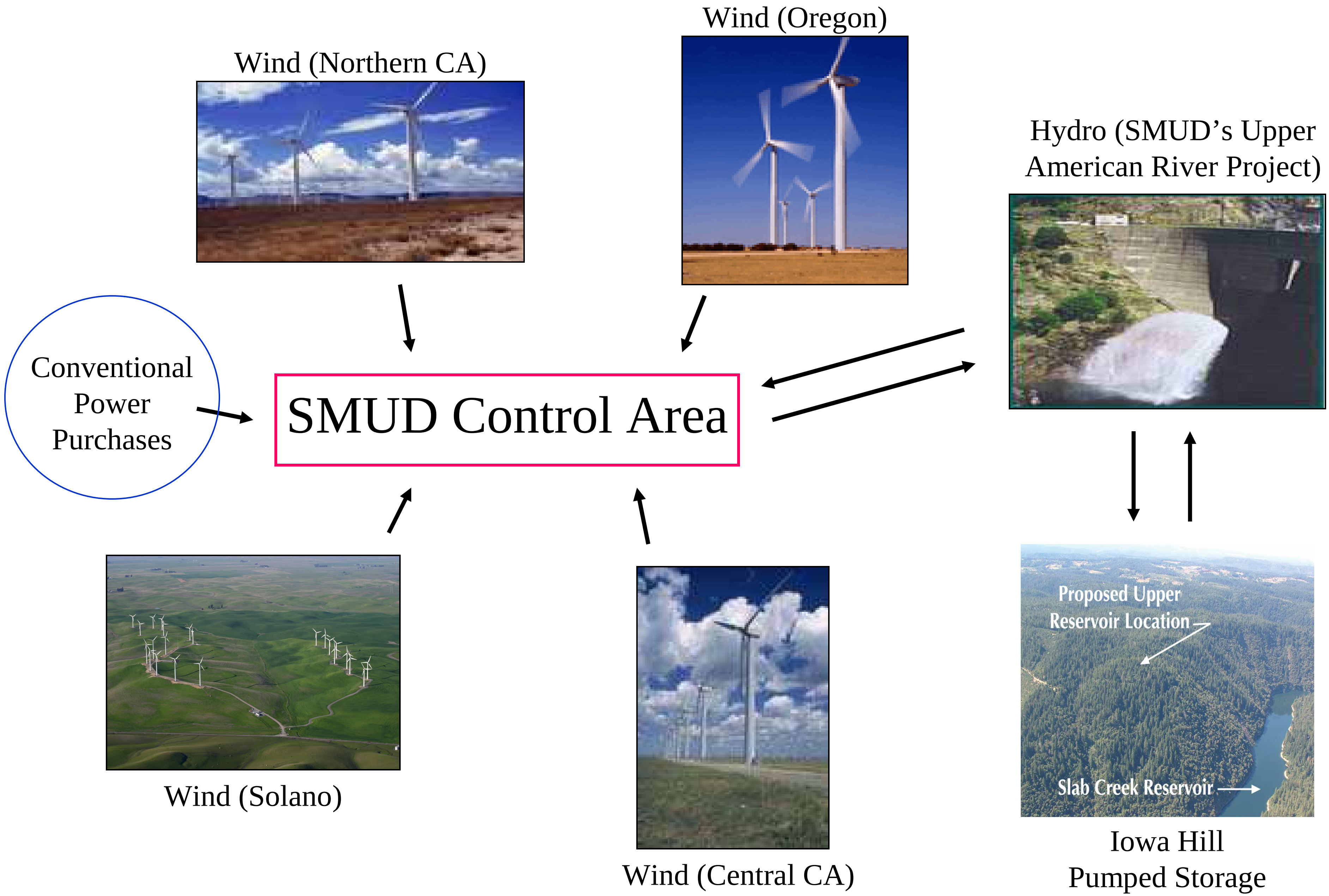


Comparing HOURLY System Load on a Hot Summer Day with Wind Production at Solano



Comparing DAILY System Load with Wind Production at Solano




Wind (Northern CA)
Wind (Oregon)
Hydro (SMUD's Upper American River Project)
Conventional Power Purchases
SMUD Control Area
Wind (Solano)
Wind (Central CA)
Proposed Upper Reservoir Location
Slab Creek Reservoir
Iowa Hill Pumped Storage

Wind Integration Study Objectives

Under Various SMUD-Defined Wind Penetration Scenarios:

- Determine the ***financial*** and ***operational*** impacts on SMUD's system
- Examine the effects of geographically dispersed wind plants on ancillary service costs and system operations
- Assess the spinning and non-spinning reserve requirements
- Determine the impacts of improved wind forecasting on integration costs
- Perform analyses of various pumped storage-wind integration scenarios
- Determine the capacity value of wind at different times of the year/day for planning purposes
- Identify/examine the technical barriers to high wind penetrations

Wind Integration Study Objectives – Cont'd

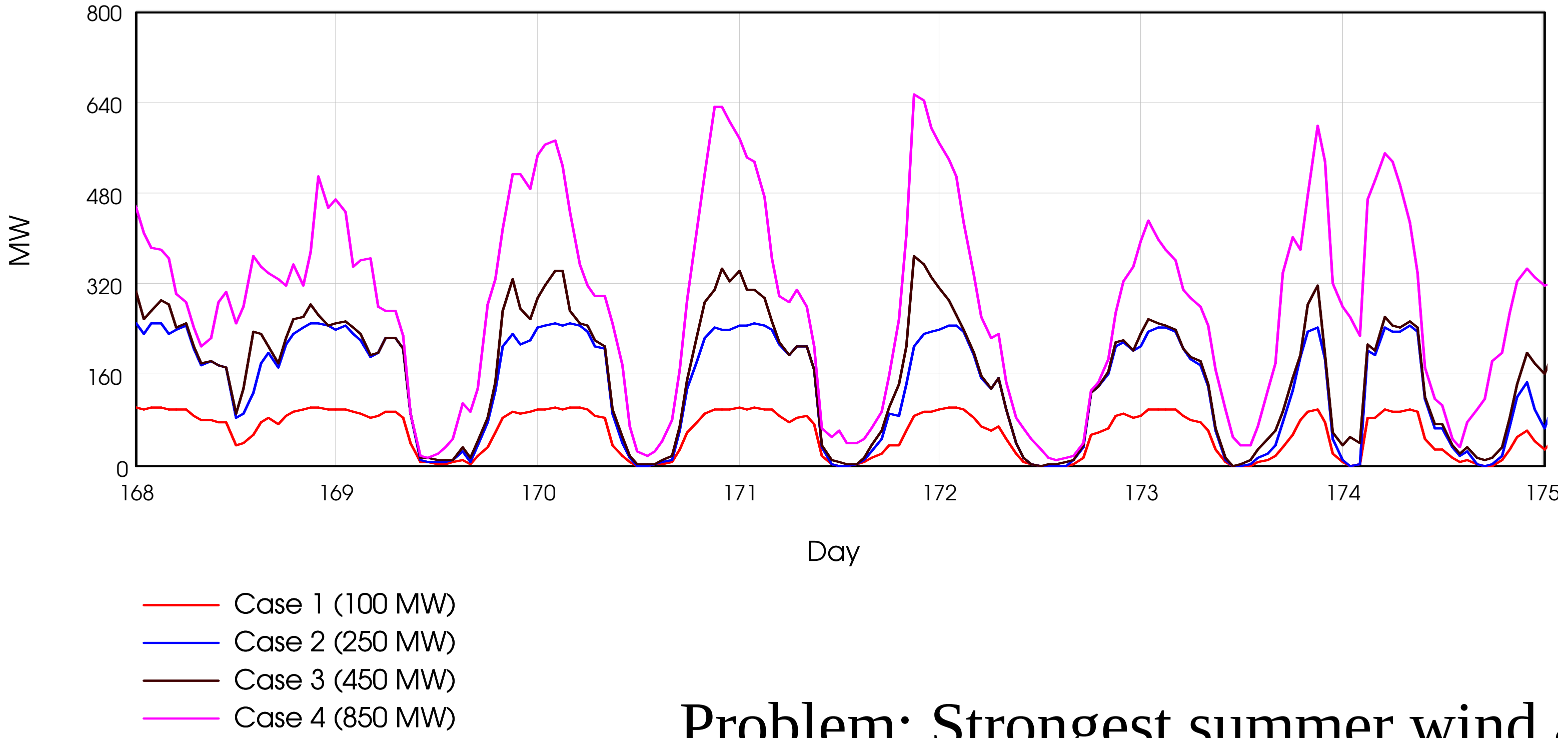
System Operations:

- Examine SMUD's current practices – planning, scheduling, operations
- Develop alternative scheduling strategies to reduce wind integration costs
- Assess the value of SMUD's continued participation in CAISO's Participating Intermittent Resources Program
- Develop recommended interconnection guidelines for wind generation
- Specify training and decision support tools, aids, and programs for SMUD Operations personnel

How SMUD Plans to Accomplish Objectives

- Develop a high-resolution wind generation model which will include an expanded Solano plant and other potential wind plants in CA & OR
- Determine the impacts of wind on control area operations using two general approaches:
  - Comparing model simulations with/without wind additions
  - Direct simulation through the development and use of a Dispatch Training Simulator Model
- Wind capacity values will be determined using formal (ELCC), approximate, and retrospective approaches
- Run simulations to examine the costs of adding next day “forecast” wind generation and compare to a reference case with zero integration cost

Example Wind Generation Model Results: Diurnal Pattern in Summer



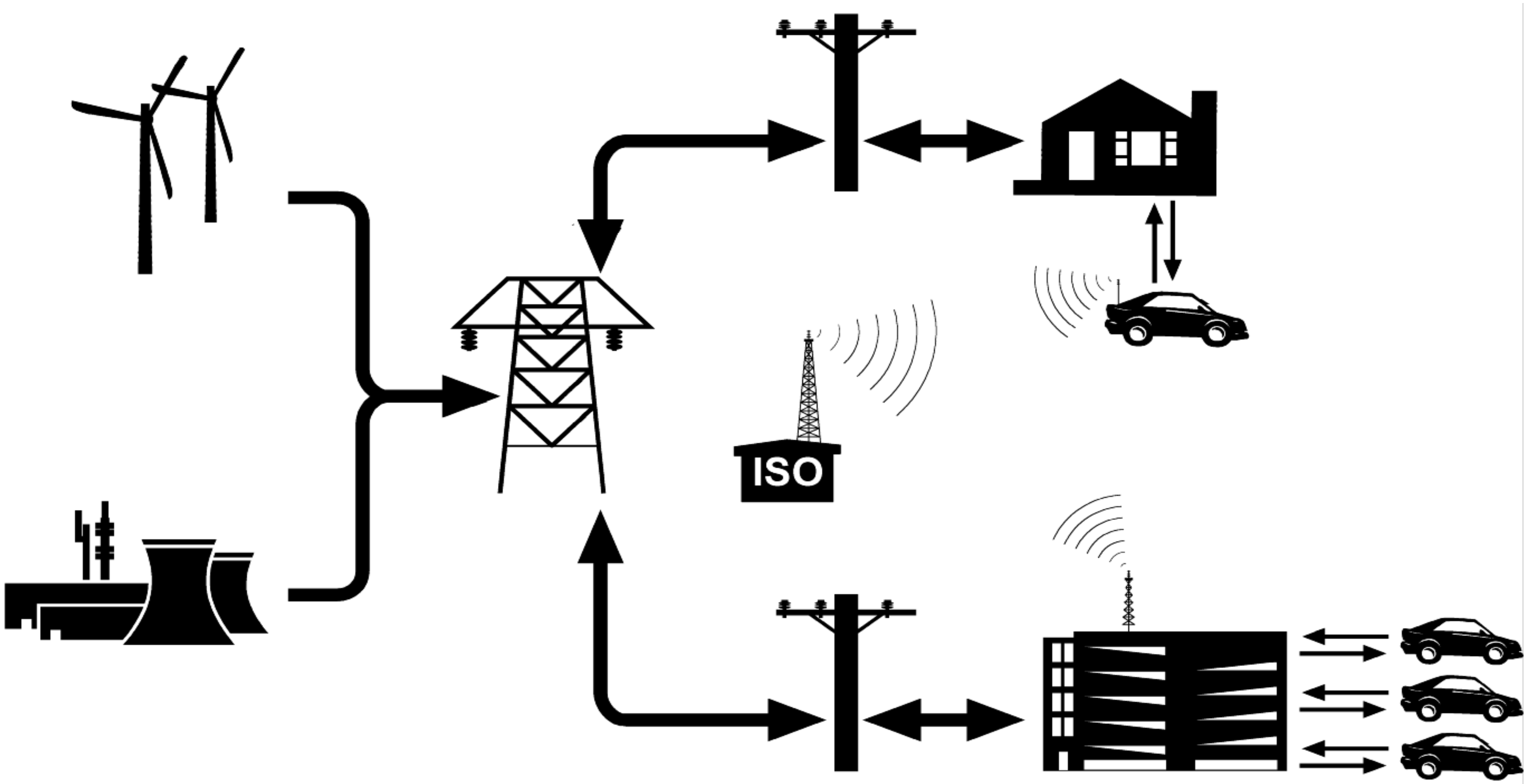
Problem: Strongest summer wind at night, greatest load at 5pm.

Problems Illustrated by Model

- Wind is cheapest, low-CO_2 emissions, but fluctuates -- How to manage?
- Problem of ancillary services (reserves, regulation) needed for minute-by-minute and hourly fluctuations
- Compare alternative overall system operational strategies:
  - Consider operating the entire generation stack differently
  - Pumped storage
  - Market purchases
  - Convert a SMUD peaker to a load-follower …..

Manage Summer Wind with V2G?

- A PARADIGM SHIFT: Storage in our customers' vehicle fleet, both responsive charging (G2V when too much wind) and discharge (V2G when not enough wind)
  - **A more modest role for V2G: Provide A/S, especially short-term regulation, to manage wind fluctuations and match to ramp rates of gas-fired generators**
  - **More aggressive: V2G as storage to move summer night wind energy to serve the next day's peak load**
- Characteristics of V2G versus centralized storage: very low capital cost, very fast response, high power/low energy (per vehicle), storage degradation (=operating cost) if deep discharge, need to prioritize driving needs
- First, we do a "back of the envelope" calculation to see if V2G would make any sense to SMUD for wind regulation, and for wind storage
- Caveat: Uncertain ability of the electrical distribution system to manage bi-directional flow of power (what % of a feeder's load can be back fed through transformers?)



From: Kempton and Tomic 2005

Full V2G for SMUD ("Back of the envelope")

- Assume Tesla or ACP vehicle: 30 kWh, 220v, 20 kW line
- SMUD: 570,000 households; 3,300 MW peak load
- Assume 1/2 of households have V2G-capable cars, of which 1/2 are available when needed, each with 1/2 storage
- V2G power: 570,000 * 1/8 * 20 kW = 1,425 MW
- V2G energy: 570,000 * 1/8 * 30 kWh = 2,138 MWh

- **Observations**:
- V2G could power nearly half of SMUD's peak load (1425 MW), with no other generation, and hold it for over an hour (2138 MWh/1425MW= 1.5 hour)
- V2G could fill in for 250 MW of wind for 8 hours

Calculating V2G Needed to Support Summer Wind

- Compare BEV: Tesla or ACP vehicle: 30 kWh, 220v, 20 kW line
- With PHEV: EnergyCS or Edrive: 9 kWh, 110v, 2 kW line
- Assume 1/2 of BEV energy available, but 3/4 of PHEV energy
- SMUD wind: 39 MW current, 250 MW Case 1, 850 MW Case 4

- For back-of-envelope, make *demanding assumptions* of need:
  - Regulation: Assume entire wind plant (100% power capacity) is backed with conventional generation
  - Diurnal storage (generation time shift): Assume all wind production is stored 12 hours (full shift of high wind at night to high load during day)
  - Assume summer wind plant capacity factor is 50% (actual/nameplate)

- Next tables show count of V2G vehicles needed for regulation (first table) and for storage (second table), at projected wind penetrations

V2G* Needed for Summer Wind Regulation

Cars on-line % households	39 MW Wind	250 MW Wind	850 MW Wind
BEV, 20 kW	1,950 0.3%	12,500 2%	42,500 7%
PHEV, 2 kW	19,500 3%	125,000 22%	425,000 74%

* Demanding assumption that 100% of wind capacity needed for regulation, but for less than 1/2 hour.

V2G Needed for Diurnal Summer Wind Storage

Cars on-line **% households**	**39 MW Wind** **(234 MWh)**	**250 MW Wind** **(1,500 MWh)**	**850 MW Wind** **(5,100 MWh)**
BEV, 15 kWh*	15,600 3%	100,000 18%	340,000 60%
PHEV, 6.75* kWh**	34,667 6%	222,222 39%	755,556 133%

*Assumes 1/2 of BEV energy available, and 3/4 of PHEV energy available.
** Given SMUD diurnal cycle of wind/load and 30 miles average drive, this would eliminate significant electric-range--so PHEV may not be suited for diurnal wind storage.

Conclusions

- BEV could offer all wind regulation and storage needed, based on back of the envelope calculations; PHEV could provide regulation but may not be large enough for diurnal wind storage
- Huge air quality and CO_2 improvements because both electric utility and transportation are improved
- Economic incentive to electrify transportation and capture value to utility--the money that would have gone to pumped storage or combustion turbines instead goes to ZEVs
- Enables much larger penetration of intermittent renewables

SMUD Perspective

- Urgency for overall Wind Integration Study results growing – expected by year end
- Potential to leverage existing investment in the SMUD Control Area model to do additional resource/operations modeling
- Potential for V2G follow-on study already evident

Next steps

- Before any planning can be done, need more detailed models of V2G-Utility operations & dispatch; SMUD has unique wind integration model and data base, at 1-minute resolution. If V2G were added, it could answer critical questions, such as
  - How much V2G would actually be dispatched? Characteristics of V2G dispatch--power, duration, frequency
  - From above, calculate cost in battery wear, value to grid
  - Is best use regulation, reserves,etc?, or also storage for diurnal shift?
  - How many cars needed for different options above?
  - Value to SMUD of new V2G regulation/storage, thus potential payment to ZEV owner?
  - AQ and GHG reductions from wind and ZEVs combined
- Cost to incorporate V2G into model under $200K (SMUD/CEC will have invested $500K developing the model and data)

Further information

- Most comprehensive references on V2G:
  - W. Kempton and J. Tomic, 2005 "Vehicle to Grid Fundamentals: Calculating Capacity and Net Revenue" J. Power Sources Volume 144, Issue 1, 1 June 2005, Pages 268-279. doi:10.1016/j.jpowsour.2004.12.025".
  - W. Kempton and J. Tomic, 2005 "Vehicle to Grid Implementation: From stabilizing the grid to supporting large-scale renewable energy". J. Power Sources Volume 144, Issue 1, 1 June 2005, Pages 280-294. doi:10.1016/j.jpowsour.2004.12.022.
- Aggregate impact of V2G to increase wind penetration, and on load curve:
  - Short, W. and P. Denholm (2006).”A Preliminary Assessment of Plug-in Hybrid Electric Vehicles on Wind Energy Markets,” NREL, TP-620-39729.
  - P. Denholm and W. Short, 2006, An Evaluation of Utility System Impacts and Benefits of Optimally Dispatched Plug-In Hybrid Electric Vehicles Technical Report NREL/TP-620-40293 July 2006
- Archival and current information on V2G:
  - www.udel.edu/V2G