



AQUIFER PUMPED HYDRO

Got a Well? Then You Have A Generator

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CALIFORNIA ENERGY COMMISSION

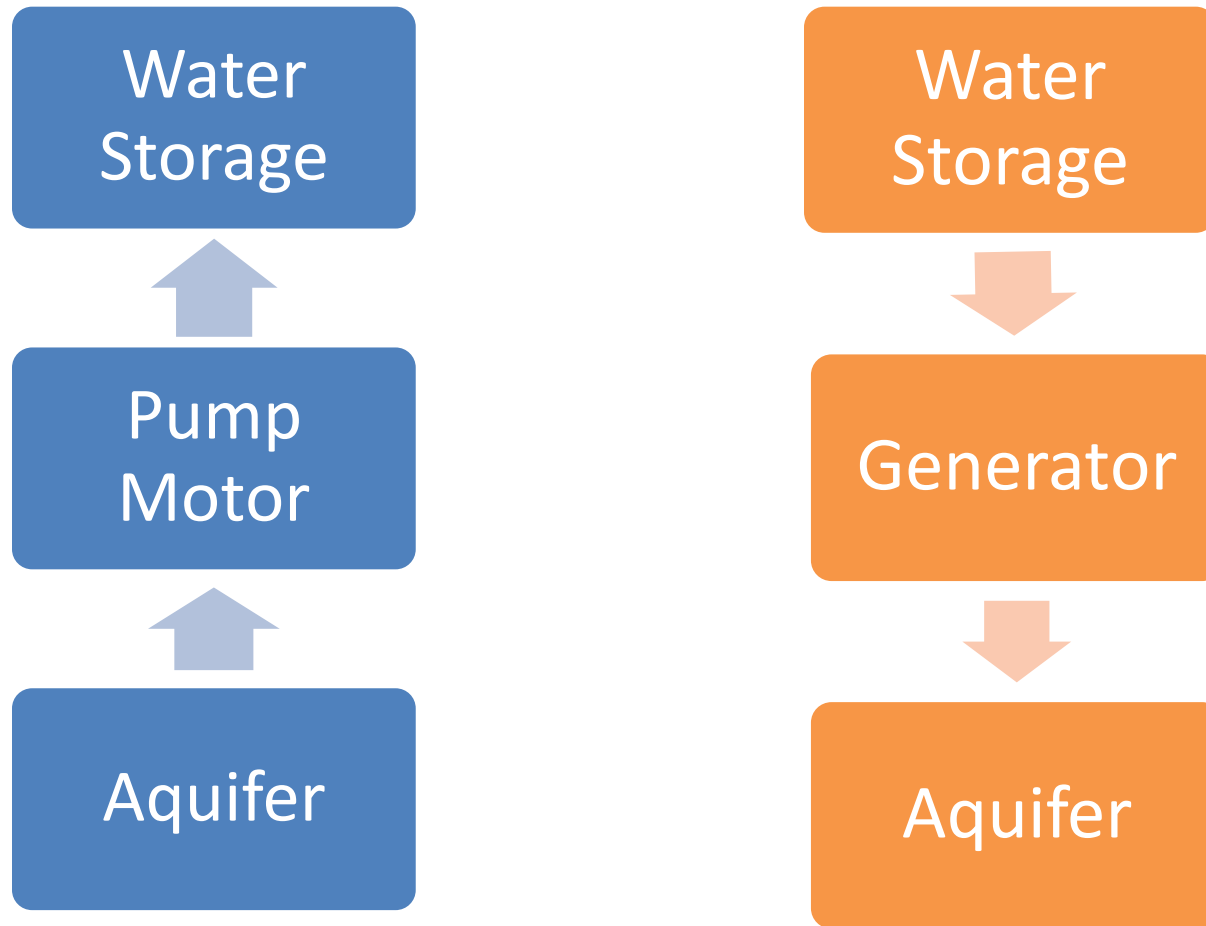
Study	Funding	Findings
1. Groundwater Bank Energy Storage Systems (EPC-15-049)	\$0.2 M from CEC	APH is feasible but not economic for new wells using existing retail rates (completed in 2017)
2. Water/Energy Bank Proof-of-Concept (EPC-16-029)	\$1.0 M from CEC	Demand Response with the State Water Project is feasible (completed in 2019)
3. 50 kW Aquifer Pumped Hydro Demonstration. Retrofit a single existing well (EPC-19-058)	\$2.0 M from CEC	Design, build, and demonstrate a 50 kW APH at one well for one year (finishes in March 2026*)
4. 200 kW Aquifer Pumped Hydro Demo. APH on a cluster of four wells. (EPC-20-008)	\$6.4 M from CEC	Demonstrate a 200 kW APH system at 4 wells for one year (finish in July 2026)

Study Evaluating Aquifer Pumped Hydro Applications (APH)

- Active groundwater injection using existing wells.

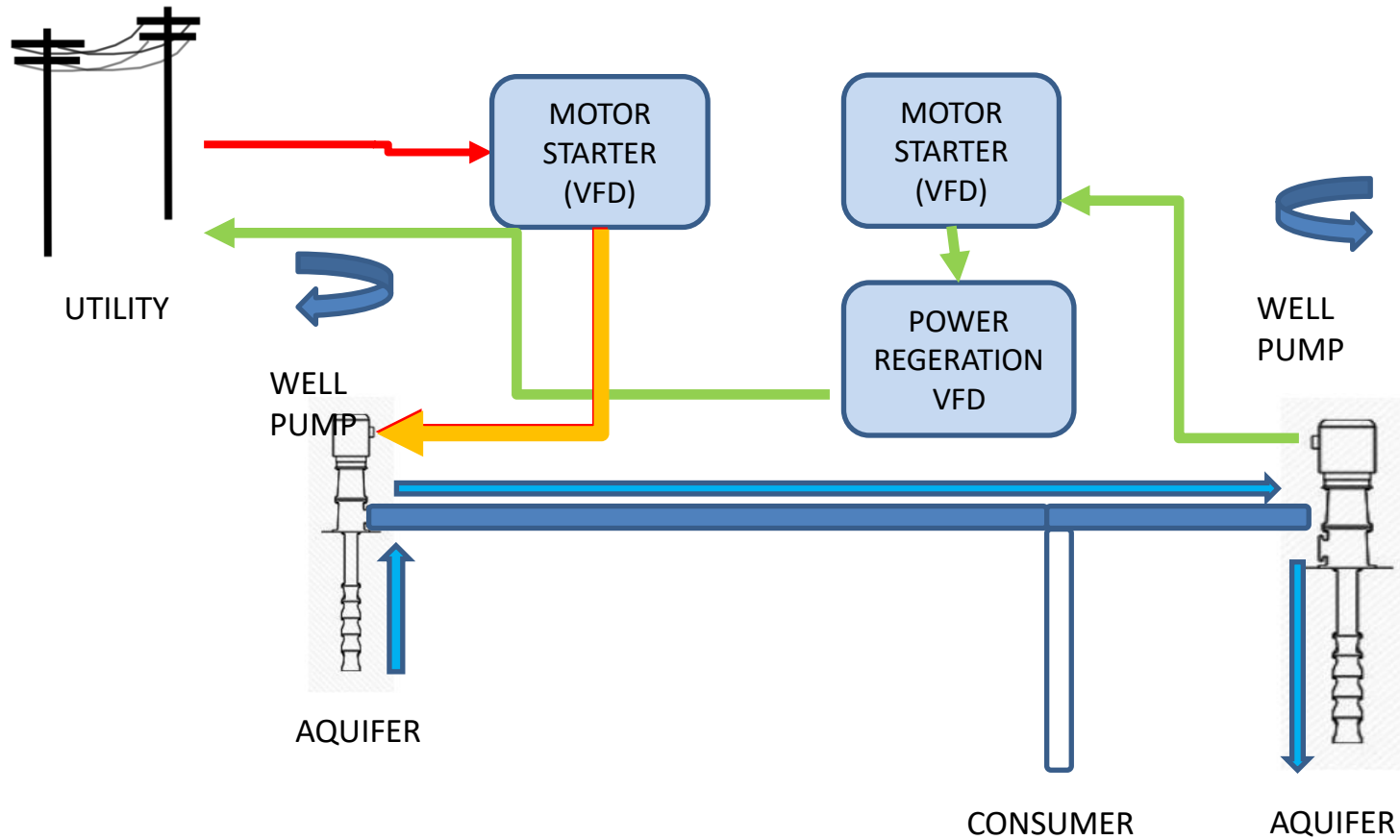
Need:

- New surface storage reservoir.
 - Motor starting requirements: VFD (Variable Frequency Drive), Soft Starter
 - Power regeneration requirements: VFD (Variable Frequency Drive), AC to DC Regeneration Module.
 - Utility interconnection interface
-
- Demonstrate:
 - Increase electricity use (pumping) in afternoons
 - Increase generation in the evening



- Well motor becomes a generator when rotated in reverse
- Idle wells provide existing infrastructure to generate electricity
- Water cycles up and down from aquifer to surface water storage reservoir

APH Schematic Using Two Wells as Illustration



Aquifer Pumped Hydro APH



During aquifer recharge process, the pumping motor is allowed to run in reverse therefore converted to a generator.

- Works in both submersible pumps and above ground vertical line shaft applications.

Motor starting requirements:

- VFD (Variable Frequency Drive) or Soft Starter or Across the Line

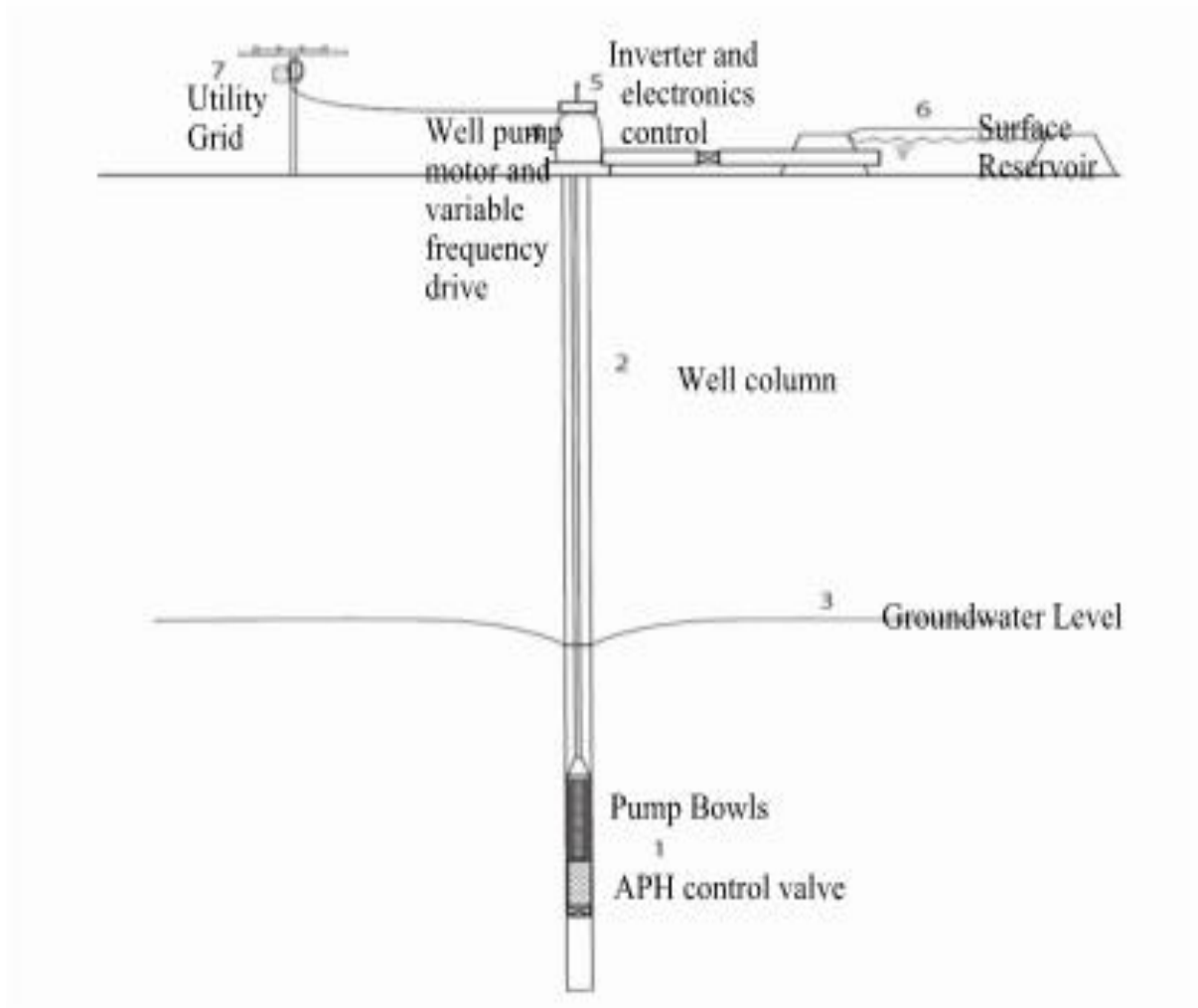
Power regeneration requirements:

- VFD (Variable Frequency Drive) and a DC to AC Regeneration module.

Benefits of APH

- Reduced net kWh cost for pumping
- Ability to shift pumping/generating times
- Possible electric utility benefits

APH Schematic and Principle Components



Aquifer Pumped Hydro (APH) Schematic

50 kW project



Existing Well Pump to APH



APH Valve



APH Valve Installed Below Pump Bowls



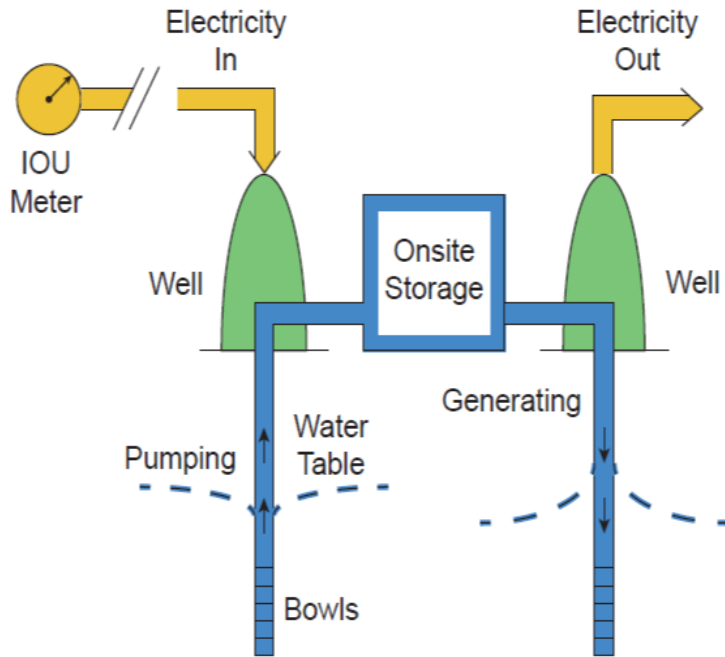
APH site with Container



APH Container with EV charger

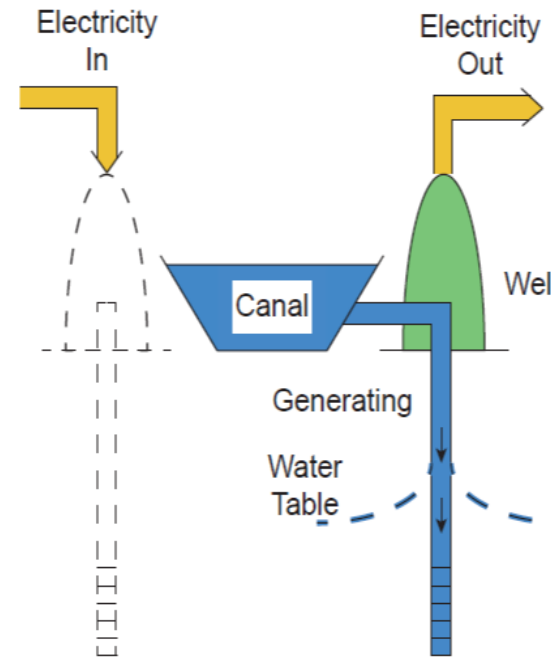
STORAGE: ENERGY IN, ENERGY OUT

Two-Way



Pumping and Generating occur at different times

One-Way



"Electricity In" occurs when farmers irrigate crops

Existing wells can store energy daily, can also produce energy during injection recharge (one way)



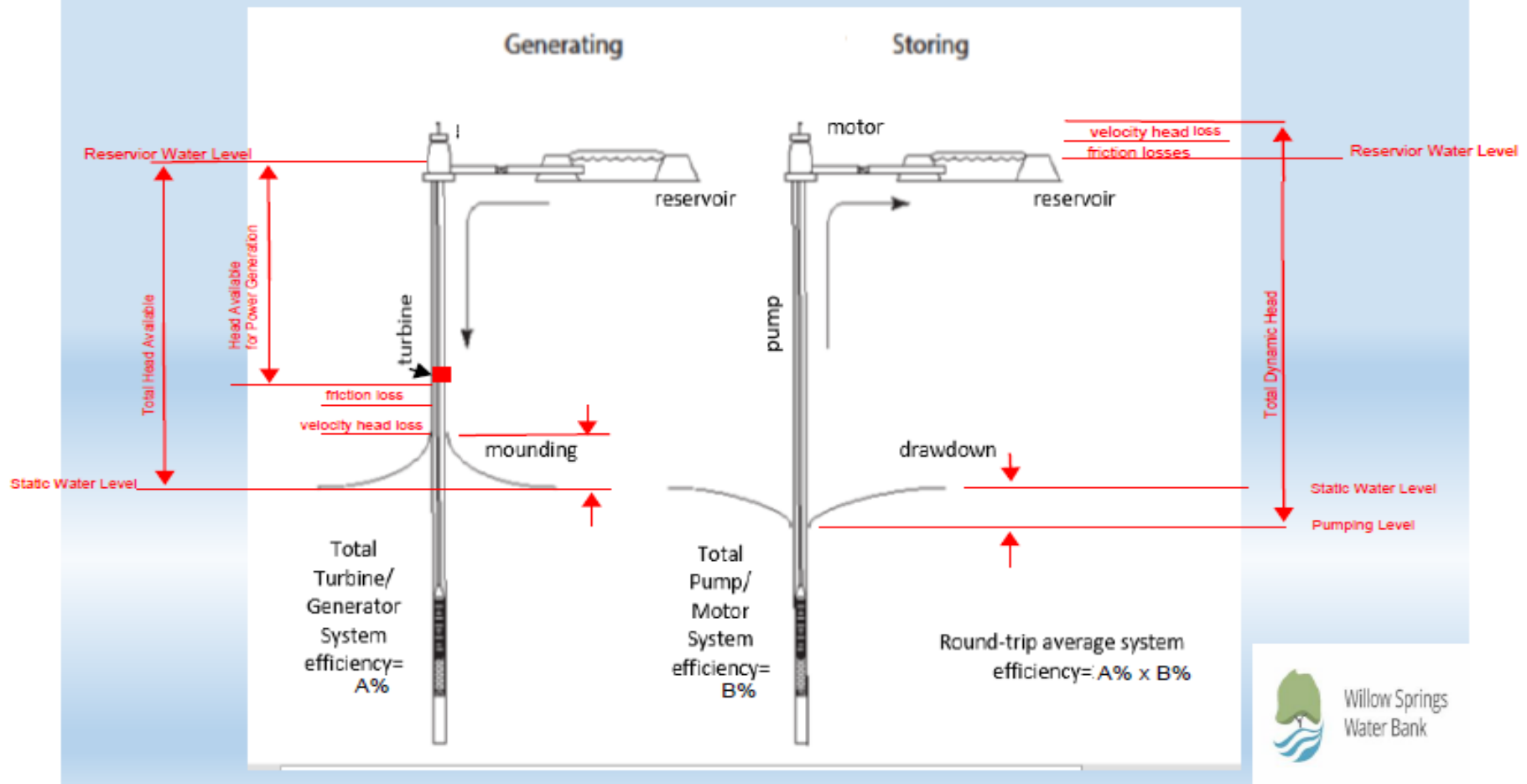
How Much Electricity Can You Generate?

Theoretical generation kilowatts (kW) = Head (feet) x Flow (cfs)

11.81

Good estimate of actual is to use 50% of theoretical generation..

Aquifer Pumped Hydro Project at Willow Springs Water Bank (WSWB)



How Much Does APH Conversion Cost?

- Simplest with VFD - constant injection, on site use. Need electronics and Regeneration Drive (\$20k)
- Constant injection rates, on site use, no VFD- need electronics, Regen drive, and VFD (\$70k)
- Intermittent injection rates, on site use, no VFD - need APH valve below pump bowls, electronics, Regen drive, VFD (\$250K)
- Most Expensive - intermittent injection, utility interconnection - APH valve, electronics, Regen drive, VFD, utility interconnection (\$300k+)

MADISON FARMS ECHO, OREGON ASR REGENERATION



200 HP MOTOR WITH VERTICAL LINE
SHAFT PUMP - 8" PIPE, AQUIFER LEVEL
520 FEET BELOW LAND SURFACE.



200 HP MOTOR STARTING VFD &
100 HP REGENERATION VFD
WITH LOCAL CONTROL PANEL.

- How efficient is your existing pump?
- What does your well column look like?
- How permeable is your aquifer?
- What is the value of the electricity produced versus electricity used for pumping?



SCE TOU-PA-3

	<u>Summer</u>	<u>Winter</u>
On peak	\$.41794	\$.13937
Mid Peak	\$.11506	\$.11102
Off Peak	\$.07823	\$.04041

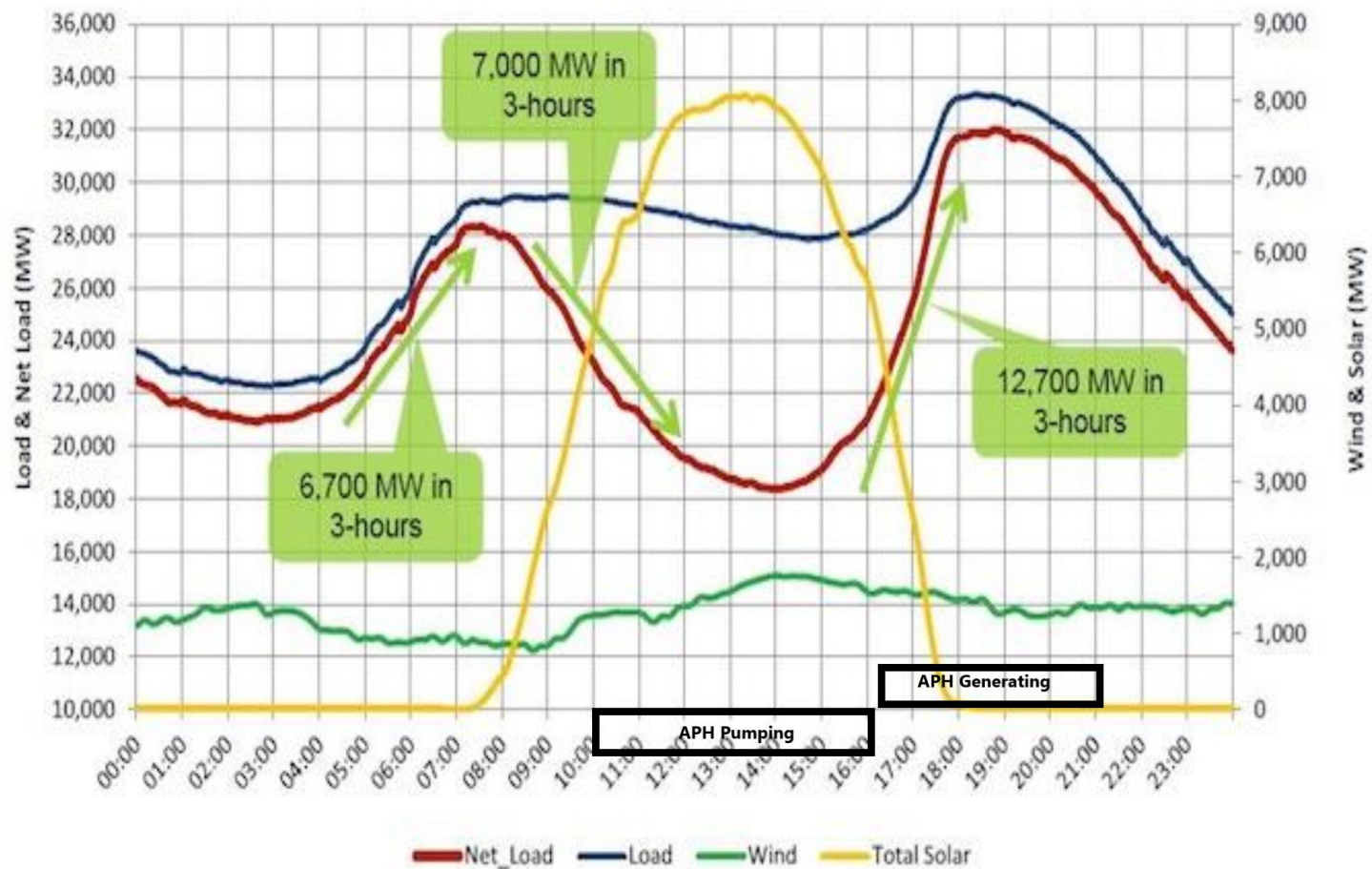
- How much water can you store on the surface?
- Is the generation going to be used on site or exported to the grid?
- Are you going to run into regulatory issues: injection of water, utility interconnection, electrical permits, etc.?

California Needs to Increase Electricity Use in the Afternoons and Increase Generation in the Evenings



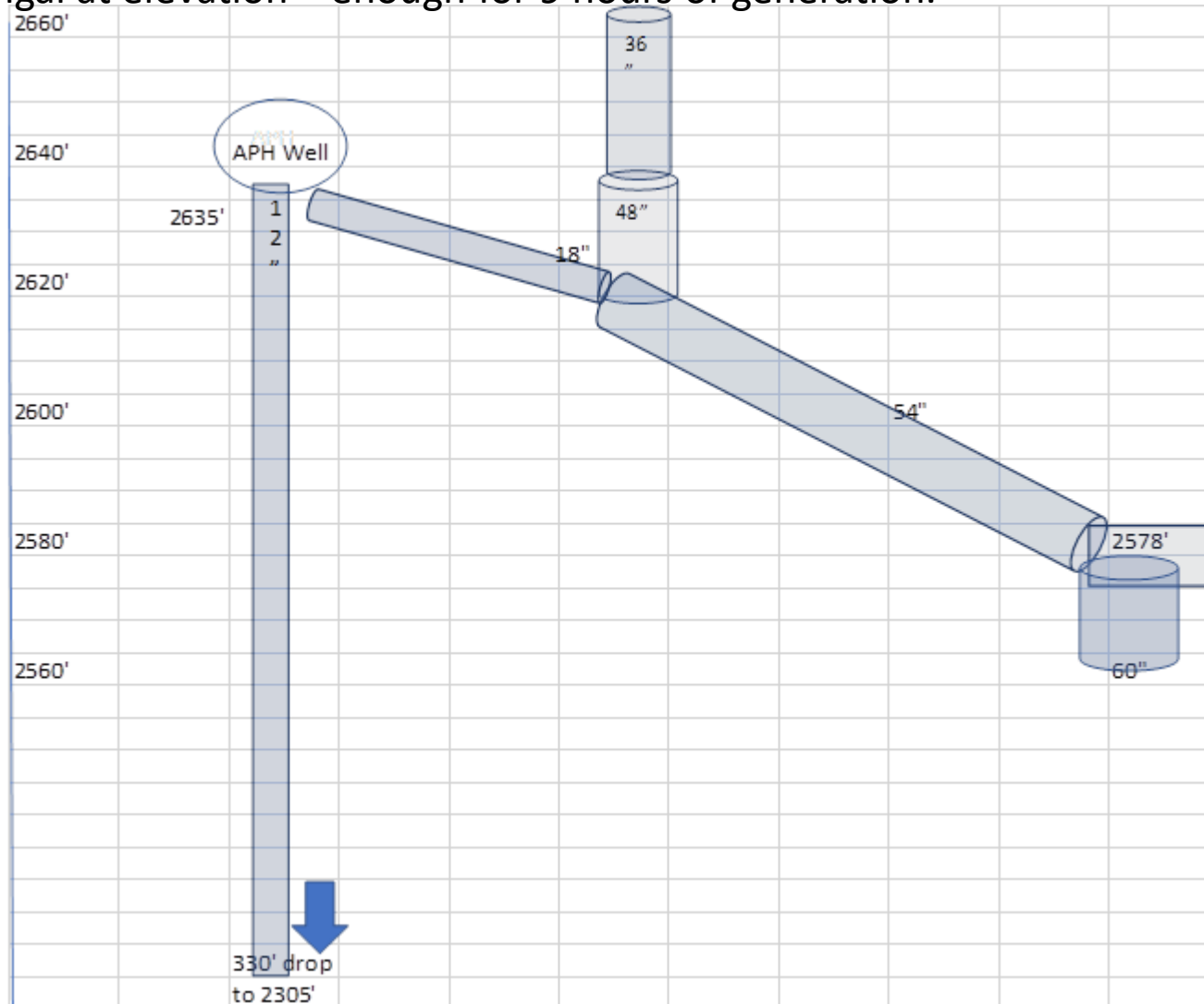
Willow Springs
Water Bank

January 2020



Using Existing Pipelines as Surface Water Storage

0.7mgal at elevation – enough for 9 hours of generation.





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