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Docket Number:	18-IEPR-03
Project Title:	Southern California Energy Reliability
TN #:	223368
Document Title:	Long-Term Viability of Underground Natural Gas Storage in California- An Independent Review of Scientific and Technical Info
Description:	This document supersedes TN# 223355 - Presentation by Jane Long with California Council on Science and Technology, for the May 8, 2018 IEPR Joint Agency Workshop on Energy Reliability in Southern California
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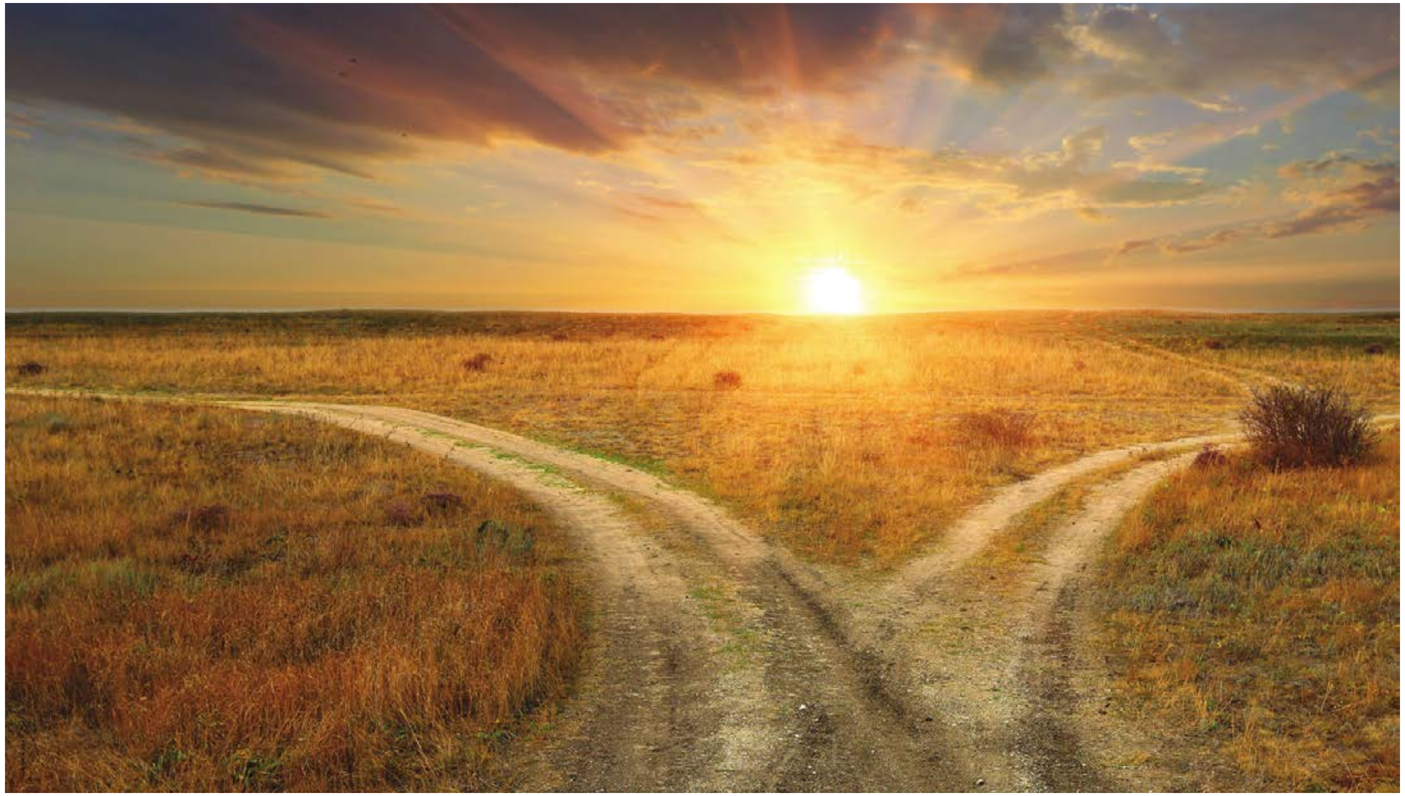
Organization:	California Council on Science and Technology
Submitter Role:	Public
Submission Date:	5/7/2018 4:18:54 PM
Docketed Date:	5/7/2018

Long-Term Viability of Underground Natural Gas Storage in California

An Independent Review of Scientific and Technical Information



Study Purpose and Key Questions

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Conduct an independent scientific assessment of the past, present, and potential future uses of underground natural gas storage in California

- **Key Question 1:** What risks do California's underground gas storage facilities pose to health, safety, environment and infrastructure?

- **Key Question 2:** Does California need underground gas storage to provide for energy reliability in the near term (through 2020)?

- **Key Question 3:** How will implementation of California's climate policies change the need for underground gas storage in the future?

Qualitative Risk-Related Characteristics

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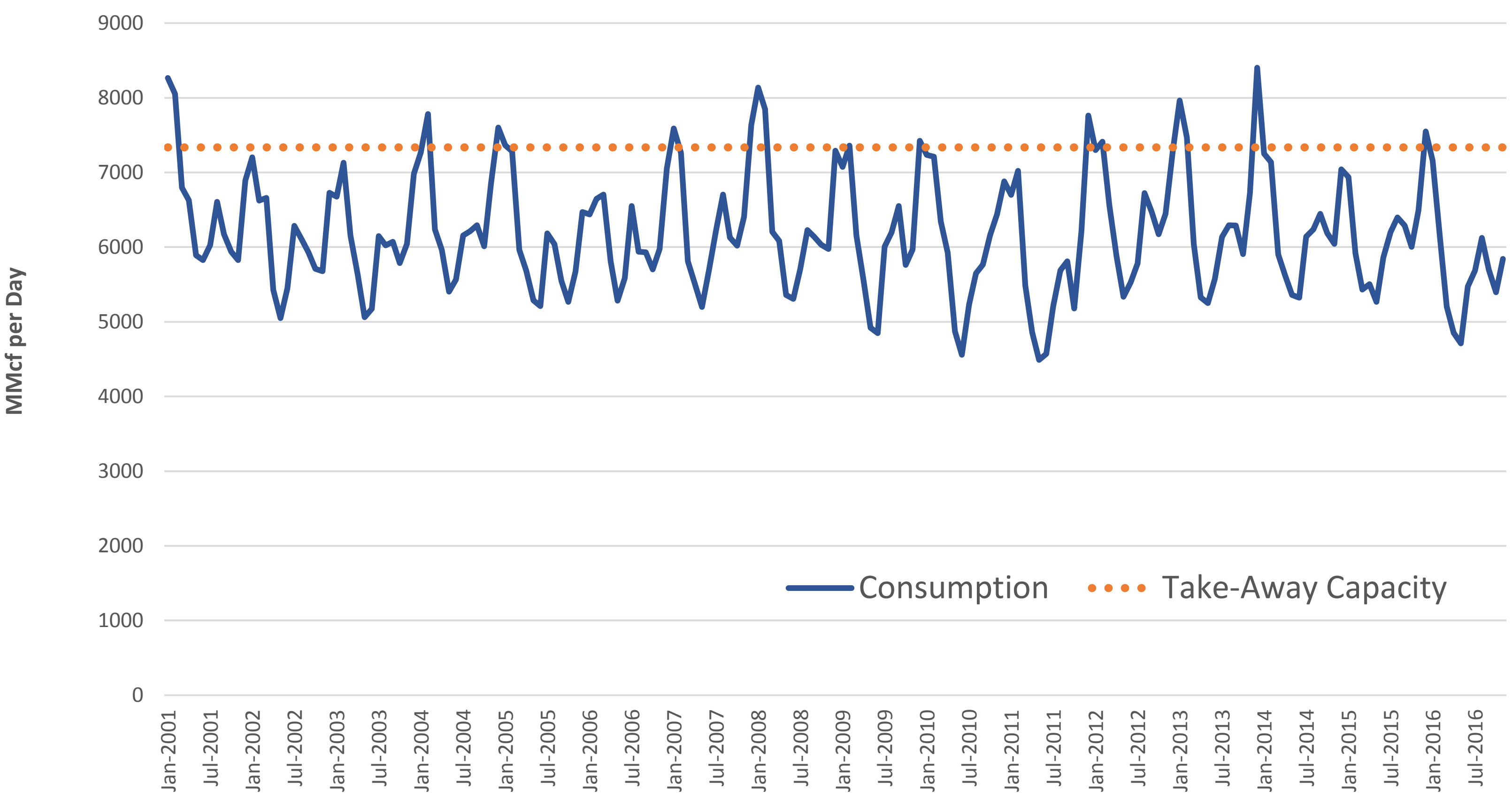
	Facility[1]	Gill Ranch Gas	Kirby Hill Gas	Lodi Gas	Princeton Gas	Wild Goose Gas	Los Medanos Gas	McDonald Island Gas	Pleasant Creek Gas	Aliso Canyon	Honor Rancho	La Goleta Gas	Playa del Rey
		Independents					Pacific Gas and Electric			Southern California Gas			
UGS facility characteristics	2015 Capacity (Bcf)	20.0	15.0	17.0	11.0	75.0	17.9	82.0	2.3	86.2	27.0	19.7	2.4
	Average depth (range) of storage reservoir(s)	5,850 6,216	1,550-5,400	2,280 2,515	2,170	2,400-2,900	4,000	5,220	2,800	9,000	10,000	3,950	6,200
	Average annual gas transfer per well per from 2006 to 2015 (million scf)	150	69	511	78	866	255	75	22	197	244	232	13
	Number of wells connected to storage reservoir in 2015	12	18	26	13	17	21	88	7	115	41	18	20
	Median age of wells as of 2015 (yrs)	39	9	15	6	11	36	41	41	60	56	63	80
Failure modes, likelihoods, and hazards	Maximum deep-seated landslide susceptibility	0	VII	0	0	0	VI	0	VII	X	X	X	X
	Last fault rupture through or (*) within 500 m of flow line(s) (yrs ago)	None	<130,000	None	None	None	<130,000*	None	None	<15,000*	<15,000*	<130,000*	None
	Hazard of Quaternary fault shearing of well(s) present	No	Yes	No	No	No	Maybe	No	No	Yes	Unlikely	Unlikely	No
	Max. 2% probability of exceeding 0.2-sec spectral acceleration in 50 years (g)	1.45	1.55	1.25	0.95	0.65	2.15	1.25	1.85	2.75	2.45	2.65	1.65
	Earthquake-induced landslide hazard zone	No	?	No	No	No	?	No	No	Yes	Yes	?	Yes
	Tsunami hazard	No	No	No	No	No	No	No	No	No	No	Yes	?
	Flooding hazard	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No	Yes	No
	Fire hazard severity zones - predominant (maximum, if different)	Not zoned (moderate)	Moderate	Not zoned (moderate)	Not zoned (moderate)	Not zoned (moderate)	Moderate	Not zoned (moderate)	Moderate	Very high	Very high	Not zoned	Very high
	Number of reported distinct LOC incidents in Evans (2008) and in Folga et al. (2016)	0	0	0	0	1	1	2	1	3	1	0	3
Health and safety	Proximity of handling plant (center) to well field (km)	0	0.7	6.5	0.9	8	0.3	0	0.4	0.2	0	0.5	0
	Population in proximity to UGS	909	401	23,771	848	195	223,069	6,473	8,821	325,330	180,359	101,371	691,757
	Median (max) formaldehyde emissions from 1996 - 2015, predominantly from compressors (lbs/yr)	4 (5)	108 (205)	1291 (1291)	not reported	not reported	4,968 (7,204)	11,163 (11,163)	not reported	15,001 (20,640)	18,675 (27,296)	2,197 (3,456)	3,038 (5,772)
GHG emissions	Average observed methane emission rate (kg CH4/hr)	88	37	0	43	35	11	150	16	200[2]	740	36	0
	Extrapolated annual emissions/average annual gas injection (%)	0.8	0.4	0	0.4	0.1	0.1	0.2	0.4	0.2[2]	1.2	0.1	0

[1]Storage in facilities whose name includes "Gas" is in depleted gas reservoirs; otherwise storage is in depleted oil reservoirs

[2]Aliso emissions measured following repair of blowout

Gas storage functions



Winter Peak Day Demand

Winter peak demand is 11.8 Bcfd

Import capacity is 7.5 Bcfd

Shortfall is 4.3 Bcfd

Without storage, California would be unable to consistently meet winter demand for gas.

There is no "silver bullet" to replace underground gas storage in the 2020 and 2030 time frame

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- Gas storage is likely to remain a requirement for reliably meeting winter peak demand. Peak demand is not projected to decrease enough by 2030 to change that.
- Two possible longer-range physical solutions include new pipelines or LNG peak shaving units would
  - be extremely expensive -- $15B eg
  - carry their own risks
  - incur barriers to siting
  - commit CA to more gas infrastructure
- No policy or market mechanisms done for electricity will have much effect on the peak winter demand because this demand is caused by demand for heat and CA has no policy to electrify heat.

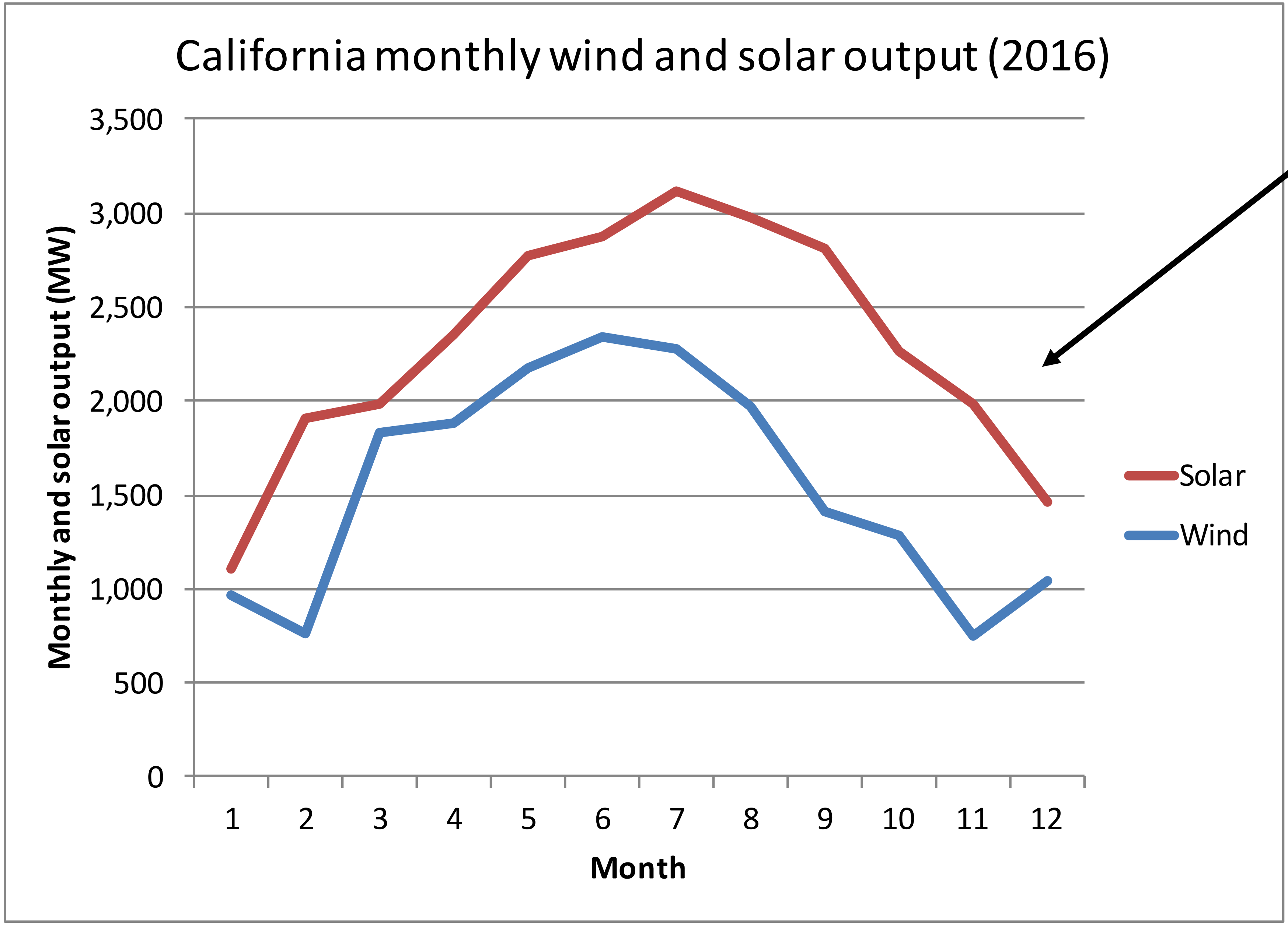

Figure 2. California monthly average wind and solar output in 2016. Reproduced from data in CAISO (2017a, Figure 1.8).

Demand for heat peaks in winter, when solar and wind outputs are minimal.

Electrified heat could be a key strategy in lowering emissions, but would further exacerbate supply-demand mismatch.

Required backup from gas equal to renewable energy capacity

Projected 2030 electricity capacities

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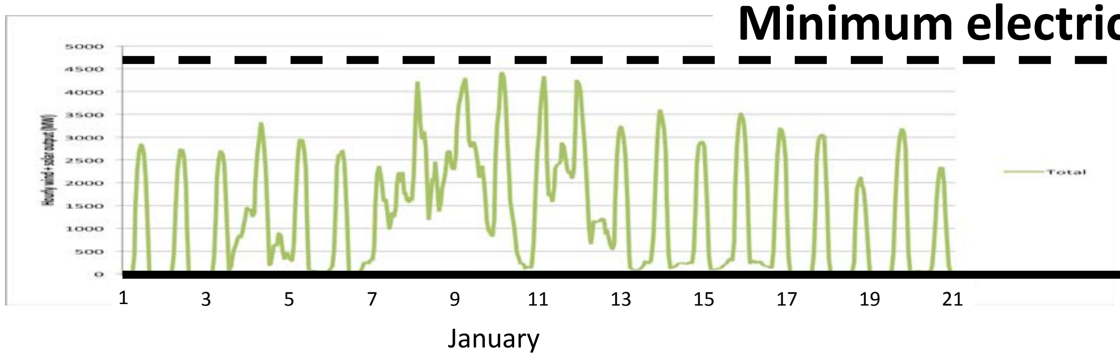
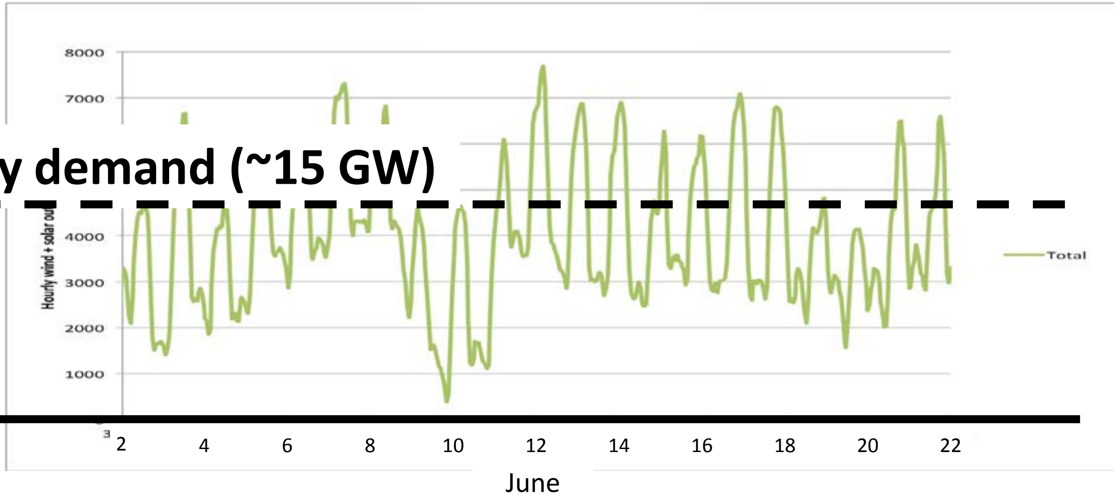
Peak electricity demand (~60 GW)

Average electricity demand (~35 GW)

Minimum electricity demand (~15 GW)





Daily load balancing of electricity

- How to address *dunkelflaute* (“dark doldrums”) conditions?
- Peak electricity demand ~60,000 MW

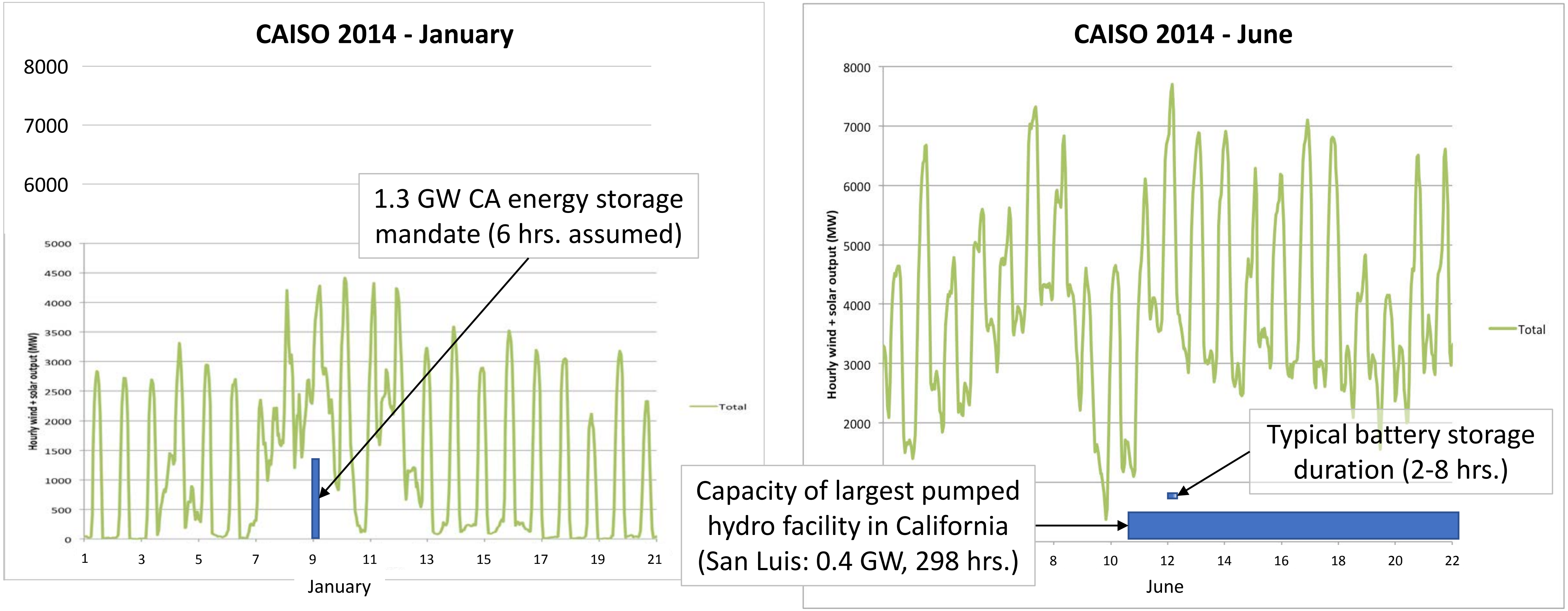
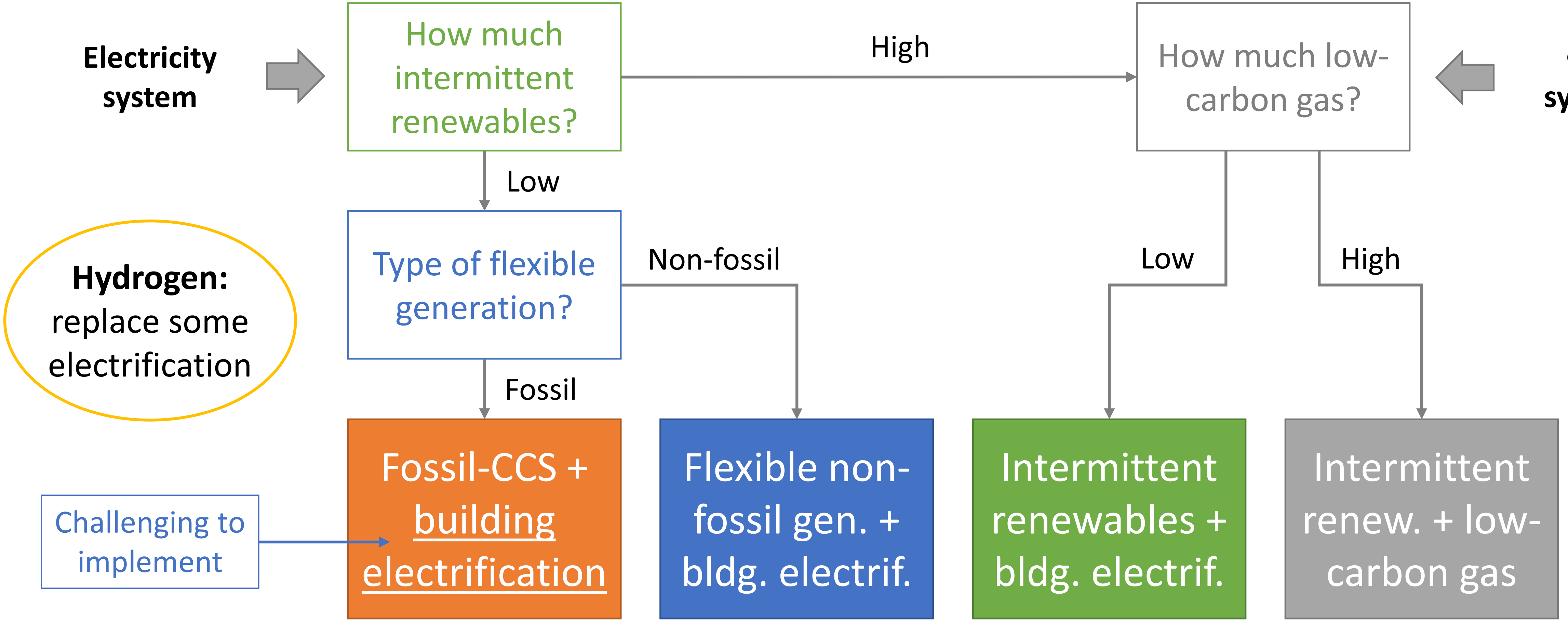


Figure ES-3.2. *Combined wind and solar output*

Logic diagram for 2050 scenarios



	Fossil-CCS + building electrification	Flexible non-fossil gen. + bldg. electrif.	Intermittent renewables + bldg. electrif.	Intermittent renew. + low-carbon gas
NG use vs. today:	~150%	~40%	~60%	~100%
Net UGS impact:	Increase	Decrease	Unclear	Unclear
New storage needed:	Yes (CO_2)	No	No	Maybe (H_2, CO_2)

Conclusions and Recommendations

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Flexible, non-fossil generation might minimize reliability issues currently stabilized with natural gas generation.

There are widely varying ideas about energy systems that might meet the 2050 climate goals. Some of these would involve some form of gas (methane, hydrogen, CO_2) infrastructure including underground storage, and some may not require as much UGS as in use today.

California should evaluate the relative feasibility of achieving climate goals with various reliable energy portfolios, and determine from this analysis the likely requirements for any type of UGS in California.

Take Away Messages: Key Question 3

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- Energy storage, flexible loads, and imported (or exported) electricity could play a role in firming intermittent renewable energy.
- Only chemical energy storage—which requires UGS—can supply power in *dunkelflaute* conditions for multiple days and seasonally.
- Electrification of heat could increase electricity demand in winter at the same time that solar and wind output declines.
- More flexible, non-intermittent or baseload low-GHG resources (e.g. geothermal, CCS, nuclear, WY wind, wave power, etc.) could reduce UGS use significantly.
- California needs a plan for energy that accounts for both capacity and reliability at all time scales.

Concluding Remarks

- With appropriate regulation and oversight, the risks associated with underground gas storage can be managed and and mitigated.
- California's energy system currently *needs* natural gas and gas storage to run reliably.
- California's current energy planning does not include adequate feasibility assessments of the possible *reliable and low carbon* future energy system configurations.