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Comments on Staff Workshop on Strategies to Model Long Duration Storage

Additional submitted attachment is included below.

Kevin Barker
Senior Manager
Energy and Environmental Policy
555 West 5th Street
Los Angeles, CA 90013
Tel: (916) 492-4252
KBarker@socalgas.com

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Jonah Steinbuck, Deputy Director
Jeffrey Sunquist, Mechanical Engineer
Research and Development Division
California Energy Commission
Docket Unit, MS-4
Docket No. 20-MISC-01
715 P Street
Sacramento, CA 95814-5512

Subject: Comments on the Staff Workshop on Strategies to Model Long Duration Storage

Dear Deputy Director Steinbuck and Jeffrey Sunquist:

Southern California Gas Company (SoCalGas) appreciates the opportunity to provide comments on the November 17, 2021 Staff Workshop on Strategies to Model Long Duration Storage. We support the California Energy Commission (CEC) funding meaningful research to analyze the needs for long duration storage. This type of research is critical given how ramifications of climate change challenge the reliability and resiliency of California's energy system. Within this effort, we believe it is equally important for the University of California Merced (UCM) Research team to consider how the use of hydrogen as a source of clean, firm, flexible power can support the decarbonization, reliability and resiliency goals and needs of the State. Specifically, developing modeling capabilities that call upon the gas system for hydrogen storage as a practical way to provide energy reliability during extreme weather and wildfire events in- and out-of-state. We also strongly encourage the consideration of a broader analysis of hydrogen that can be incorporated in the UCM Research team's draft report.

Our comments build upon UCM's existing research approach and output by providing the following feedback for consideration:

a) A broader view of a hydrogen transportation and storage network in California can enable long-duration hydrogen storage as required to help California provide greater grid resilience.
b) Understanding and building upon previous studies and real-world applications is needed to help California manage a balanced portfolio of energy resources.
c) Analyzing the costs and accessibility of storing hydrogen underground in various geologic formations in the UCM Draft Storage Technology Summary, such as depleted gas fields and hard rock caverns.

d) Modeling cross-sector hydrogen storage is crucial for evaluating the decarbonization and resiliency capabilities of the gas system.

e) Any assessment of long-duration storage should consider future changes to the hydroelectric system to provide a comprehensive understanding of challenges and opportunities in long-duration storage strategies for California.

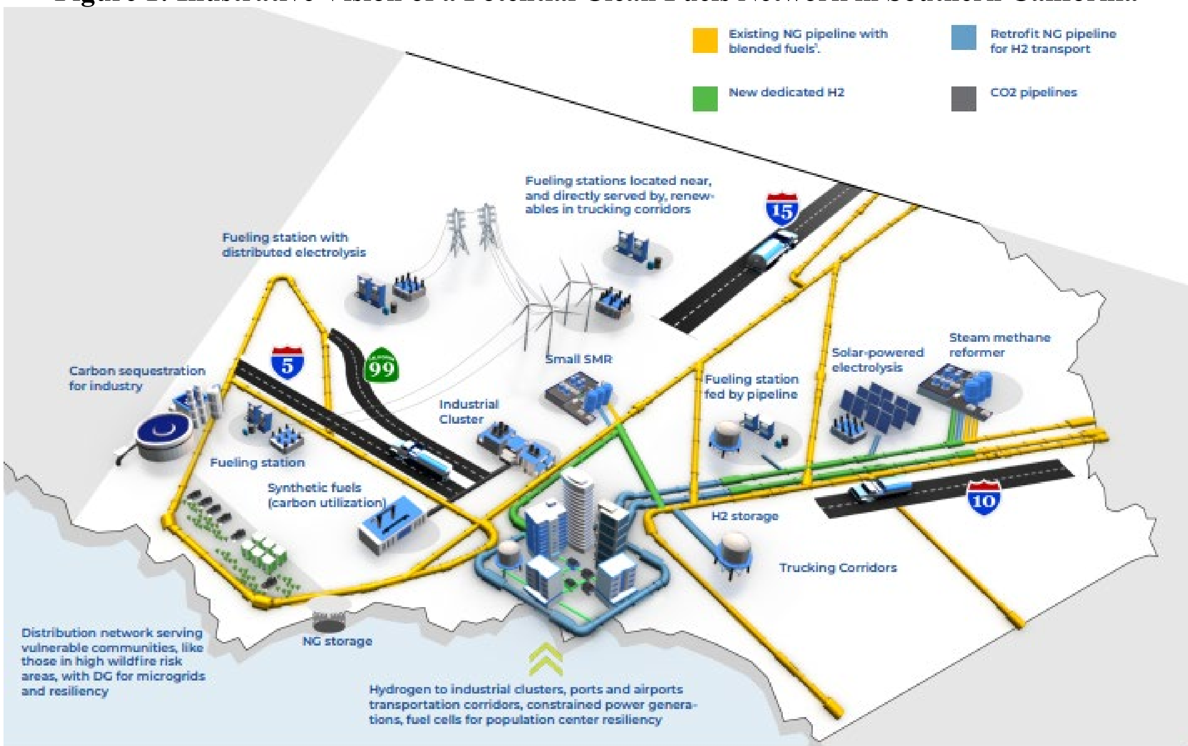
a) A broader view of a hydrogen transportation and storage network in California can enable long-duration hydrogen storage as required to help California provide greater grid resilience.

A large-scale hydrogen transportation and storage network does not currently exist in California. Utilizing the existing natural gas grid to transport hydrogen through blending in addition to building out a dedicated hydrogen pipeline network could encourage long-term, inter-seasonal storage of hydrogen, support renewable generation optimization, and increase electricity resiliency. There is a distinct value proposition for policymakers to support hydrogen infrastructure development by implementing hydrogen policies to scale the adoption of hydrogen energy storage, which would then drive down costs. SoCalGas's Clean Fuels Report describes the detailed buildout of a potential clean fuels network in Southern California.[1] As depicted in Figure 1, a clean fuels transmission backbone system has the potential to serve thermal generators, trucking routes, and match industrial hydrogen demand with hydrogen supply. When handling substantial hydrogen volumes, "[m]ultiple natural gas transmission pipelines would need to either blend hydrogen alongside natural gas or be retrofitted for hydrogen transport."[2]

[1] *See* SoCalGas Clean Fuels Report, available at: https://www.socalgas.com/sites/default/files/2021-10/Roles_Clean_Fuels_Full_Report.pdf.

[2] *See* SoCalGas Clean Fuels Report, Page 43.

Figure 1: Illustrative Vision of a Potential Clean Fuels Network in Southern California[3]



The European Hydrogen Backbone (EHB) initiative, a consortium of European Gas Transmission System Operators (TSOs), is considering a similar approach. The EHB initiative evaluated the role of hydrogen infrastructure in Europe and assessed the potential of retrofitting existing natural gas pipeline infrastructure for hydrogen. The EHB initiative highlights that hydrogen pipeline retrofits occur parallel to existing natural gas pipelines. The EHB report notes the need for approximately 28,000 miles of dedicated hydrogen pipeline by 2040. Approximately 70 percent of the needed pipeline can leverage repurposed existing natural gas infrastructure.[4] Similar to this project in Europe, parallel hydrogen pipelines in Southeastern California could help to facilitate a retrofit process.

Additionally, hydrogen produced from excess electricity by electrolysis can be injected into the gas pipeline or stored in a dedicated hydrogen pipeline network. Both alternatives are scalable and comprehensive energy storage solutions that can play a vital role in electricity decarbonization and flexibility by optimizing and synchronizing energy resources and providing a much-needed linkage between variable renewable electric resources, seasonal energy storage, and dispatchable electric generation. Enabling hydrogen technologies in California will help mitigate renewable curtailment and seasonal energy imbalances when total renewable generation is below average, and demand remains high via some thermal load electrification.

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[3] *See* SoCalGas Clean Fuels Report, Page 44.
[4] "European Hydrogen Backbone grows to 40,000 km, covering 11 new countries," April 13, 2021, available at: https://gasforclimate2050.eu/news-item/european-hydrogen-backbone-grows-to-40000-km/.

b) Understanding and building upon previous studies and real-world applications is needed to help California manage a balanced portfolio of energy resources.

This comment is regarding the UCM Presentation on Strategies to Model Long-Duration Storage. SoCalGas recently commented on a new framework of long-duration storage within the California Public Utilities Commission (CPUC) Order Instituting Rulemaking (OIR) 20-05-003 to continue electric integrated resource planning and related procurement processes. Specifically, SoCalGas supported an effort to evaluate procurement issues associated with long-duration storage resources across a diverse set of technology platforms, including hydrogen-fueled resources. Analyzing the value of renewable hydrogen as a key energy storage technology for California can provide greater value from research outputs, directly benefiting stakeholders. Hydrogen can offer long-duration/seasonal storage solutions and should be part of this balanced portfolio of procurement strategies. Developing an analytical Integrated Resource Planning (IRP) modeling methodology and a scenario framework that includes leveraging the existing gas grid for hydrogen use and storage through blending to evaluate the impact of long-duration energy storage resources with longer discharge durations (e.g., days, weeks, and months) will be essential under deep decarbonizations scenarios.

Long-duration energy storage will be a critical resource component that can complement daily renewable overgeneration resources by utilizing the electricity rather than curtailing it. Relying on energy generation with intermittent and seasonal variability presents major challenges because these resources cannot be ramped up and down to serve demand over the course of a day, across a few days, or from season to season. As the renewable energy mix on the grid increases to over 60 percent, resource planning models are predicting that energy production will exceed "demand in over 20% of the hours of the year, totaling between 5% and 10% of all renewable power produced."[5] Addressing this seasonal imbalance will require large-scale storage resources capable of storing power over longer duration cycles. The long-duration and seasonal need for storing renewable energy will increase as California moves towards 100 percent clean energy goals.

Recent net-zero emissions energy systems studies[6,7] note that many essential energy services (across multiple sectors of the economy) cannot be accommodated without the use of resources that can be produced, stored, transmitted, distributed, and converted back to electricity with zero emissions when needed. Renewable hydrogen as a long-duration or seasonal energy storage resource can serve this strategic need. Schmidt et al. (2019)[8] in their recent study addressing the future levelized costs of energy storage technologies evaluated the technology suitability of nine different energy storage solutions under 12 different grid use applications as shown below. The study identifies hydrogen as one of the key energy storage technologies that is best for long-duration discharge applications. The study also identifies that hydrogen is one of the two technologies that can offer grid support services across all 12 applications. Table 1 below depicts a qualitative overview of electricity storage applications and technology suitability included in the

[5] Integrating Clean Energy Technologies with Existing Infrastructure. Available at: http://www.apep.uci.edu/PDF_White_Papers/Integrating_Clean_Energy_013020.pdf
[6] *Ibid*
[7] Net-zero emissions energy systems, Davis et al., (2018). Available at: https://www.researchgate.net/publication/326049153_Net-zero_emissions_energy_systems
[8] Study available at: https://www.sciencedirect.com/science/article/pii/S254243511830583X

study. Renewable hydrogen as a long-duration or seasonal storage resource can serve the strategic need to support essential energy services across multiple sectors of the economy and enhance system resiliency by providing local and in-state storage capabilities.[9]

Table 1: A Qualitative Analysis of Electricity Storage Application and Technology Suitability[10]

Role	Application	Pumped Hydro	Compressed Air	Flywheel	Lithium Ion	Sodium Sulfur	Lead Acid	Vanadium Redox Flow	Hydrogen	Supercapacitor
System Operation	1. Energy arbitrage	✓	✓		✓	✓	✓	✓	✓	
	2. Primary response			✓	✓	✓	✓	✓	✓	✓
	3. Secondary response	✓	✓	✓	✓	✓	✓	✓	✓	✓
	4. Tertiary response	✓	✓		✓	✓	✓	✓	✓	
	5. Peaker replacement	✓	✓		✓	✓	✓	✓	✓	
	6. Black start	✓	✓	✓	✓	✓	✓	✓	✓	✓
	7. Seasonal storage	✓	✓					✓	✓	
Network Operation	8. T&D investment deferral	✓	✓		✓	✓	✓	✓	✓	
	9. Congestion management	✓	✓		✓	✓	✓	✓	✓	
Consumption	10. Bill management				✓	✓	✓	✓	✓	
	11. Power quality			✓	✓	✓	✓	✓	✓	✓
	12. Power reliability				✓	✓	✓	✓	✓	

c) Analyzing the costs and accessibility of storing hydrogen underground in various geologic formations in the UCM Draft Storage Technology Summary, such as depleted gas fields and hard rock caverns.

SoCalGas commends the UC Merced Research team for the thoughtful inclusion of Table *2* included within the Draft Storage Technology Summary (Draft Summary),[11] which depicts a high-level summary of strengths and policy needs for various energy storage technologies, including hydrogen. In the discussion on storage technology descriptions, the Draft Summary states

[9] Long-duration storage technologies provide tremendous value to the State especially given the importance of local storage technologies in supporting a reliable and resilient energy system. For example, a commissioned report prepared by the California Council on Science and Technology (CCST) indicated that local underground gas "storage could increasingly be called on to provide gas and electric reliability during emergencies caused by extreme weather and wildfires in and beyond California. Both extreme weather and wildfire conditions are expected to increase with climate change. These emergencies can threaten supply when demand simultaneously increases."

[10] *See* Projecting the Future Levelized Cost of Electricity Storage Technologies, Schmidt, et. al., January 2019, Pages 81-100, available at: https://www.sciencedirect.com/science/article/pii/S254243511830583X

[11] *See* Draft Storage Technology Summary, November 2021, available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=240545&DocumentContentId=73865.

"[hydrogen] underground storage can be relatively inexpensive, but it is not readily available in many locations."[12] It is unclear what the Draft Technology Summary is referring to in this instance, as underground hydrogen storage is under development in various geologic formations, such as salt cavern storage, lined rock cavern storage, and depleted gas fields. In fact, a recent Bloomberg NEF report, "Hydrogen: The Economics of Storage," evaluated eight major hydrogen storage technologies that could be utilized. The report found that rock caverns are "[t]he next best large-scale storage solution in locations without salt caverns, as they have the potential to store hydrogen for $0.71/kg, which [researchers] postulate could fall to $0.23/kg if abandoned tunnels or mines can be used."[13] The report also found that depleted oil and gas fields "could be especially good at storing large volumes for long periods."[14] Table 2 (below) shows the different storage options of which five are in current use and three are being further explored.[15]

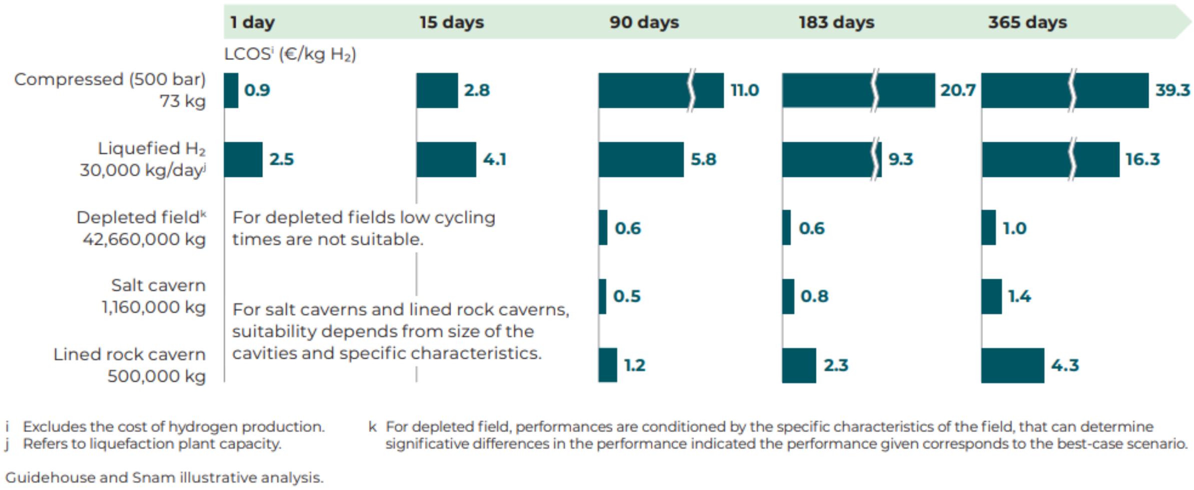
Table 2: Hydrogen Storage Options Summarized, Based on Identified Criteria by Bloomberg NEF[16]

	Gaseous state				Liquid state			Solid state
	Salt caverns	Depleted gas fields	Rock caverns	Pressurized containers	Liquid hydrogen	Ammonia	LOHCs	Metal hydrides
Main usage (volume and cycling)	Large volumes, months-weeks	Large volumes, seasonal	Medium volumes, months-weeks	Small volumes, daily	Small - medium volumes, days-weeks	Large volumes, months-weeks	Large volumes, months-weeks	Small volumes, days-weeks
Working capacity (t-H_2)	300-10,000t per cavern	300-100,000t per field	300-2,500t per cavern	5-1,100kg per container	0.2-200t per tank	1-10,000t per tank	0.18-4,500t per tank	0.1-20kg
Pressure (bar)	45-275	70-280	20-200	Up to 1,000	Ambient	Ambient	Ambient	~10
Benchmark LCOS ($/kg)[1]	$0.23	$1.90	$0.71	$0.19	$4.57	$2.83	$4.50	Not evaluated
Possible future LCOS[1]	$0.11	$1.07	$0.23	$0.17	$0.95	$0.87	$1.86	Not evaluated
Flexibility	Medium	Low	Medium	High	Medium	Medium	Medium	Medium
Losses (% H_2 lost / year)	Near-zero	2%	Near-zero for lined caverns	Near-zero	50%	Near-zero (if re-liquefied)	Near-zero	Near-zero
Parasitic load (% H_2 HHV)[2]	1 - 2.5%	1 - 2.5%	1 - 2%	0.5 - 11%	25 - 33%	25 - 28%	29-33%	11 - 28%
Density (kg/m^3)[2]	4 - 20	4 - 20	4 - 20	3.5 - 50	70.8	107 - 121	47 - 57	40 - 140
H_2 purity after release	High	Low	High for lined caverns	High	High	May need purification	High	High
Geographical availability	Limited	Limited	Limited	Not limited	Not limited	Not limited	Not limited	Not limited
Technological readiness[3]	TRL 9	TRL 2 - 3	TRL 2 - 3	TRL 9	TRL 7 - 9	TRL 9	TRL 7 - 9	TRL 7 - 9
Commercial readiness[3]	CRI 4	CRI 2	CRI 2	CRI 5 - 6	CRI 1 - 4	CRI 1 - 5	CRI 2	CRI 4
Social acceptability[4]	High	High	Medium	High	High	Low	Medium	High
Safety concerns[4]	Low	Low	Low	Medium	Medium	High	Medium	Medium

[12] *See* Draft Storage Technology Summary, November 2021, Page 30.
[13] *See* Hydrogen: The Economics of Storage, Full Report, Bloomberg NEF, July 2019.
[14] *Ibid*
[15] Five technologies that are used today include: pressurized vessels, liquid hydrogen, salt caverns, ammonia, and metal hydrides. A further three that are being explored for potential use include: depleted gas fields, rock caverns, and liquid organic hydrogen carriers.
[16] *See* Hydrogen: The Economics of Storage, Full Report, Bloomberg NEF

Additionally, Figure 2 (below) shows the estimation of levelized costs of storage (LCOS) in euros per kilogram of hydrogen for different storage options.[17] Researchers found that long-term, seasonal underground storage (90-365 days) is economically feasible, while short-term storage options (less than 1-15 days) are more costly at present.[18] Given the research discrepancies, we recommend that the UCM team study the costs and accessibility of storing hydrogen in other geologic formations, specifically in depleted oil and gas fields and hard rock caverns.[19]

Figure 2: Estimation of LCOS in €/kg H_2 for different hydrogen storage options[20]



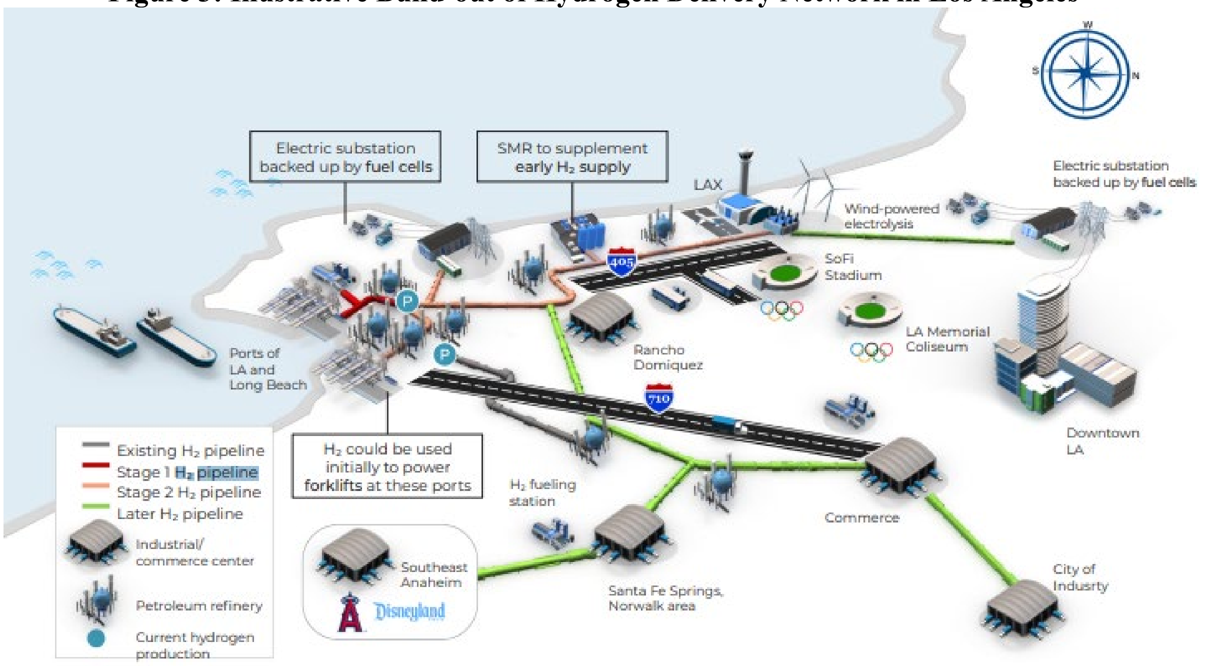
d) Modeling cross-sector hydrogen storage is crucial for evaluating the decarbonization and resiliency capabilities of the gas system.

As stated in the Draft Summary, "the opportunity for the use of cross-sector storage has not been consistently included in capacity expansion models, but such use could provide one of the best solutions for seasonal storage."[21] SoCalGas underscores the important opportunity that cross-sector storage of hydrogen can provide for the broader California economy and statewide emissions reduction objectives and agrees with Sarah Kurtz's explanation that "cross-sector energy storage is often omitted from long-duration modeling, but could be critical for resilience…such examples include hydrogen for transportation, hydrogen from underground storage…"[22] Further, the SoCalGas Clean Fuels Report highlights the important critical infrastructure that needs to be in place to transport hydrogen to support the future electricity generating needs of the City of Los Angeles by as early as 2025-2030.[23] An illustrative buildout of a hydrogen delivery network in Los Angeles is included below to provide a practical prototype for the use of cross-sector storage

[17] "Market state and trends in renewable and low-carbon gases in Europe," Gas for Climate and Guidehouse, December 2021, at 29. Available at mst_report_oct21_211126_11h00.indd (gasforclimate2050.eu).
[18] *Ibid.*
[19] *See* Hydrogen: The Economics of Storage, Full Report, Bloomberg NEF, July 2019.
[20] "Market state and trends in renewable and low-carbon gases in Europe," Gas for Climate and Guidehouse, December 2021, at 29. Available at mst_report_oct21_211126_11h00.indd (gasforclimate2050.eu).
[21] *See* Draft Storage Technology Summary
[22] *See* Strategies to Model Long Duration Storage, Presentation by Sarah Kurtz and UC Merced Research Team, available at: https://efiling.energy.ca.gov/getdocument.aspx?tn=240421
[23] *See* SoCalGas Clean Fuels Report, Page 62.

across transportation, hydrogen production, and various other downstream applications in Southern California and beyond.

Figure 3: Illustrative Build-out of Hydrogen Delivery Network in Los Angeles[24]



From a state incentive perspective, distinguishing between storage, long-duration storage, and generation resources and technologies can be significant. We respectfully suggest that the research team fully explore the roles that storage plays in balancing the grid, urge the modeling of all potential storage technologies, and consider how State incentives impact expansion and growth of technologies. For example, while it is true that biogas may be viewed as a generating technology, biogas also represents energy storage that can be stored seasonally in existing infrastructure and is useful in balancing the grid. When modeling energy pathways, including and considering a wide range of generation and storage technologies helps to better understand their role and value as storage resources that can help meet the State's SB 100 goals by providing a reservoir of energy to balance the grid.

Based on the above, we recommend expanding the UCM's analysis in two ways. First, as the report aptly suggests to "optimize the hydrogen production by considering the capital costs and operating costs of the electrolyzers offset by the value of the hydrogen that is generated, potentially turning curtailed electricity into a revenue stream," a more complete model would calculate the cost of using hydrogen (that is being stored for transportation or chemical use) to generate electricity when electricity is in short supply.[25] Second, we suggest incorporating work completed around Clean

[24] *See* SoCalGas Clean Fuels Report, Page 62.
[25] *See* Draft Storage Technology Summary at 5.

Firm Power,[26] which is currently missing from the bibliography for the Draft Electricity Generation Technology Summary. Clean firm power, like hydrogen, is clean and dispatchable power, available on demand. The above-referenced research indicates significant affordability and land use benefits to using clean firm power, finding that "across all modeled sensitivity cases, portfolios with at least one clean firm power option are 32-53% cheaper than the renewable energy and batteries only portfolio."[27] The research also found that having more options of clean firm power available would result in the lowest-cost mix of clean firm resources needed to assist during times of *dunkelflaute.*[28]

e) Any assessment of long-duration storage should consider future changes to the hydroelectric system to provide a comprehensive understanding of challenges and opportunities in long-duration storage strategies for California.

As California experiences a changing climate,[29] longer-term shifts and variability in weather patterns will present ongoing and future risks to the electric grid and infrastructure. For instance, the U.S. Government Accountability Office's (GAO's) 2021 report found that more frequent droughts and changing rainfall patterns may adversely affect hydroelectricity while increasing wildfire activity due to warmer temperatures and drier conditions may reduce transmission capacity or damage distribution lines.[30] Further, an increase in the intensity, frequency, and duration of weather events could cost utilities and customers billions, including the costs of power outages and infrastructure damage.[31] Long-duration (seasonal) storage is not a new phenomenon in California's energy system. The backbone of the energy system has been hydroelectric systems and gas storage because of their ability to store energy for months at a time for use in the distant future. This unique capability of hydroelectricity and gas storage allows for hedging costs to keep costs affordable for end-users.

Hydroelectric generation is the longest-running supply-side resource in California. In fact, in the 1940s, it made up about 60 percent of the electricity supply. Pondage hydro is recognized as long-duration storage (*e.g.,* hourly, or daily). However, climate change could have drastic impacts on the seasonal storage capacity of snowpack, which is invaluable to the hydroelectric system. The late Spring and Summer melt-off from the snowpack generates carbon-free electricity and provides power as temperatures and demand rise. As average temperatures increase, it is projected that there will be considerably less snowpack because more precipitation will fall as rain rather than snow.

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[26] *See* California Needs Clean Firm Power, and So Does the Rest of the World, Environmental Defense Fund, Stanford University, Princeton University, Energy & Environmental Economics, Clean Air Task Force, UC San Diego, and the Brookings Institute, available at: https://www.edf.org/sites/default/files/documents/SB100%20clean%20firm%20power%20report%20plus%20SI.pdf

[27] *See* California Needs Clean Firm Power, and So Does the Rest of the World, Page 7.

[28] *A term of German origin which describes renewable energy events where there is minimal or no sunshine and wind for extended periods, usually occurring during winter – it is specifically a problem of low electricity output that occurs in highly-renewable electricity systems.*

[29] *See* California Department of Resources Recycling and Recovery Webpage: California Has Been Devastated by the Climate Crisis. Available at https://www.calrecycle.ca.gov/organics/slcp.

[30] *See* Statement of Frank Rusco, Director of U.S. Natural Resources and Environment, Before the Committee on Environment and Public Works, U.S. Senate on the U.S. Government Accountability Office's Report Electricity Grid Resilience: Climate Change Is Expected to Have Far-reaching Effects and DOE and FERC Should Take Actions, March 10, 2021. Available at https://www.gao.gov/assets/gao-21-423t.pdf.

[31] *Ibid., at 2.*

This is important because if there is excess water that dams cannot hold, they will release the water early in the season. Therefore, the electricity is generated early (*i.e.,* winter months) rather than being continuously stored for summer months when demand is high. Climate change will reduce the amount of natural long-duration storage that Californians have relied on. Thus, it is important to model the variability in hydro storage (*i.e.,* snowpack) to provide a comprehensive understanding of the challenges and opportunities in long-duration storage strategies for California.

Conclusion

SoCalGas appreciates the opportunity to comment on the Staff Workshop on Strategies to Model Long-Duration Storage. We respect the insights provided by the UCM Project team from this study thus far. However, focusing on renewable hydrogen as provided for above can provide grid support services across various applications and will allow for a robust and reliable electricity system; a reliable and robust electricity system will have the greatest GHG and other air pollutant emission reductions benefits. SoCalGas looks forward to collaboratively pursuing our common interest of lowering GHG emissions today and in the future.

Respectfully,

/s/ Kevin Barker

Kevin Barker
Senior Manager
Energy and Environmental Policy