PROGRESS REPORT for EPC-19-060

April 2023

Recipient Project Manager: Sarah Kurtz

Commission Agreement Manager: Jeffrey Sunquist

What we planned to accomplish this period

1. We will continue to meet with stakeholders and community representatives to gather inputs and request feedback
2. We will extend our calculations on the effects of variable solar profiles to include multiple long-duration energy storage options
3. We will calculate the effect of the EV charging profiles on the need for energy storage
4. We will complete a draft of a paper about the potential for oxycombustion for California
5. We will complete a draft of a paper about the opportunity for hydrogen generation.
6. We will prepare to begin to prepare for the public workshop in June and for the draft outline of the final report which is due at the end of June

What we actually accomplished this period

1. Stakeholder and collaborator meetings: During the last month, we met with:

- Roderick Go of E3

It's clear that we had a slow month in meeting with our partners. We will work on doing better this summer as we are getting some results ready to share.

2. We will extend our calculations on the effects of variable solar profiles to include multiple long-duration energy storage

We are working on a draft of a paper that will capture attention from solar developers. Without long-duration energy storage, the curtailment in 2045 is strongly affected by the solar profile, as shown in Fig. 1. This is expected since the south-facing tilt results in more electricity generation during the winter compared with zero tilt, thus reducing the GW of solar that are selected to be deployed. We anticipate that it will be less expensive to implement the fixed-tilt system and more expensive to implement a tilted, tracked system relative to today's well optimized tracked, no-tilt systems. Because of the uncertainty of the cost differential, we have run the calculations for a range of costs for each mounting configuration.
The costs for implementing the elements of the same simulations are shown in Fig. 2.

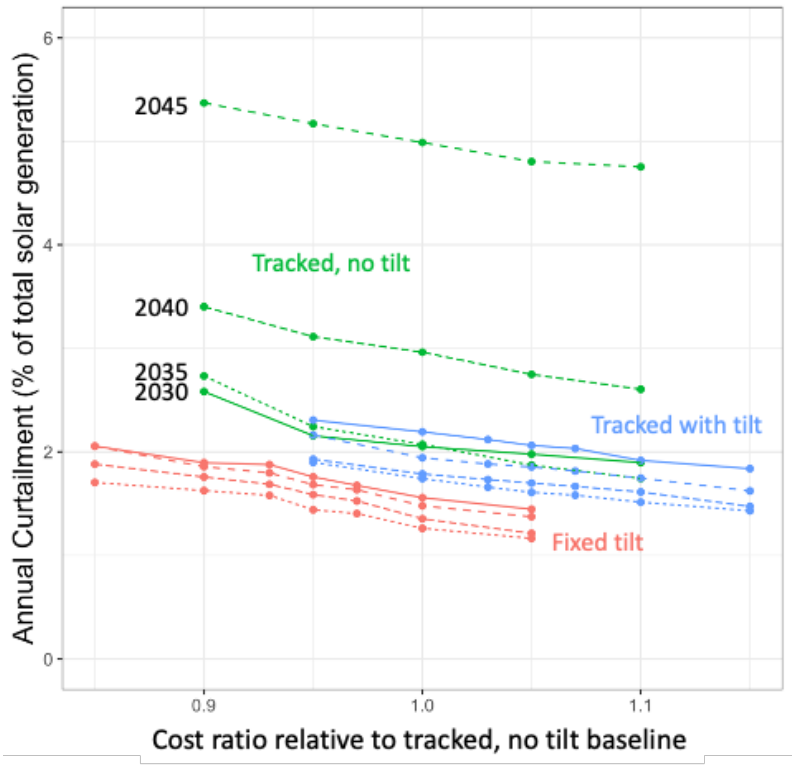

Fig. 1. Fraction of solar generation curtailed as a function of the cost of the solar for three solar mounting configurations for 2030, 2035, 2040, and 2045

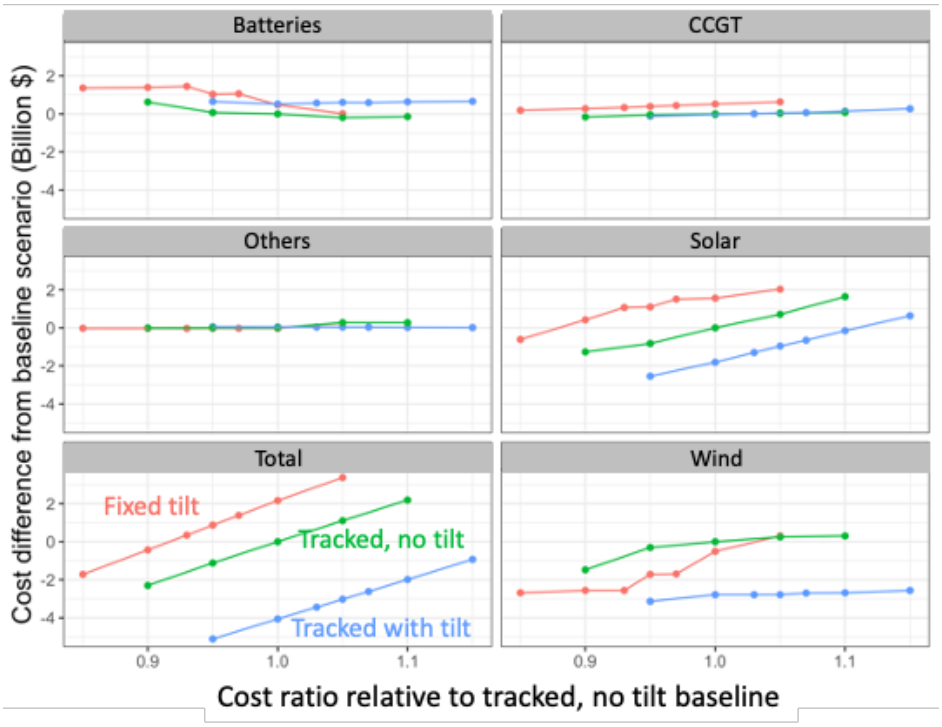

Fig. 2. Costs for system elements as a function of the cost of the solar for three solar mounting configurations

It's interesting to note that the storage (modeled as 4-h Li batteries in this simulation) cost increases when fixed tilt is used. This is not surprising since more batteries are required to get through the night. However, the surprising result was that the model selects less wind for the solar that has south-facing tilt. We expect that this is because the south-facing solar does a better job of matching the seasonal demand, so tends to displace investment in wind generation.

3. *We will calculate the effect of the EV charging profiles on the need for energy storage*

A recent paper by Gagnon and Cole[1] studied the effect of adding substantial amounts of load (for example, adding EV charging) at different times of day. The figure below compares the effects of adding a nighttime load (left pie chart), a daytime load (center pie chart), or a constant load (right pie chart). The result is quite striking: adding load during the daytime results in the model selecting deployment of mostly solar and wind, while the nighttime and constant loads resulted in addition of more natural gas and coal.

These profiles are more extreme than the ones we have selected.

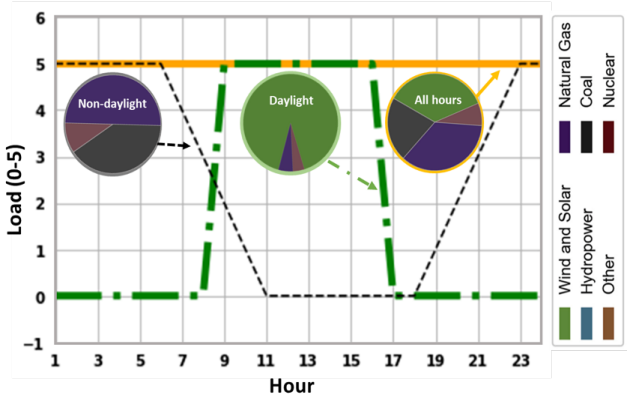

Fig. 3 Data taken from Gagnon and Cole[1] and replotted to show important result

When studying the 3 selected EV load profiles for California, we find that the effect is significant. When using low-cost (so that it displaces 4-h batteries) 8-h, 85% long-duration energy storage (LDES) compared with adding no new EV load, the Happy hour profile increases the selected storage by 19% while the High residential access profile increases the selected storage by 30% as shown in Fig. 4. A similar calculation, but for 12-h batteries shows an increase of 22% for the Happy hour and 33% for the High residential access. In both cases, the unconstrained profile is in between the Happy hour and High residential access profiles.

[1] https://doi.org/10.1016/j.isci. 2022.103915

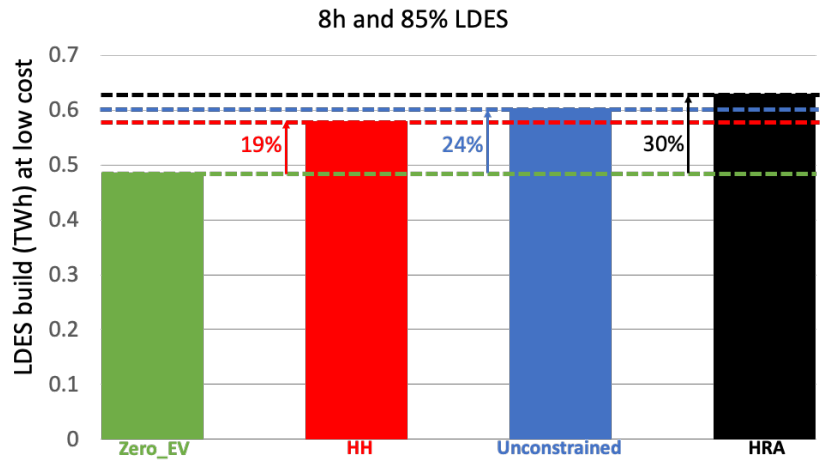

Fig. 4. Selected build of 8-h, 85% long duration energy storage for zero addition of EVs, and EV load addition using the Happy Hour, Unconstrained and High residential access profiles

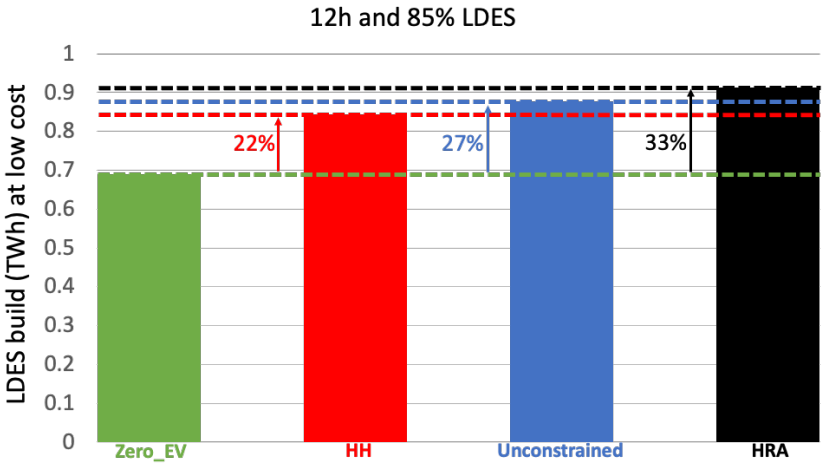

Fig. 5. Results similar to those for Fig. 4, but for 12-h, 85% LDES

We are planning to submit a draft of a paper on this topic to a conference by the end of May.

4. We will complete a draft of a paper about the potential for oxy-combustion for California

The draft was completed and submitted as an abstract for presentation at the Photovoltaic Specialists Conference. It was accepted for presentation and will be presented in early June. A copy of the abstract is attached. The draft is being refined for final submission. An extension of this work will include a more thorough analysis of LDES with different attributes and is planned to be submitted to a conference by the end of May.

5. We will be complete a draft of a paper about the opportunity for hydrogen generation

The draft is progressing well and shows the very dramatic adoption of electrolyzers when the production tax credit for green hydrogen is implemented under the Inflation Reduction Act. The online capacity selected as a function of the hydrogen selling price is compared for no tax credit (Fig. 6) with the dramatic early adoption that occurs with the tax credit (Fig. 7).

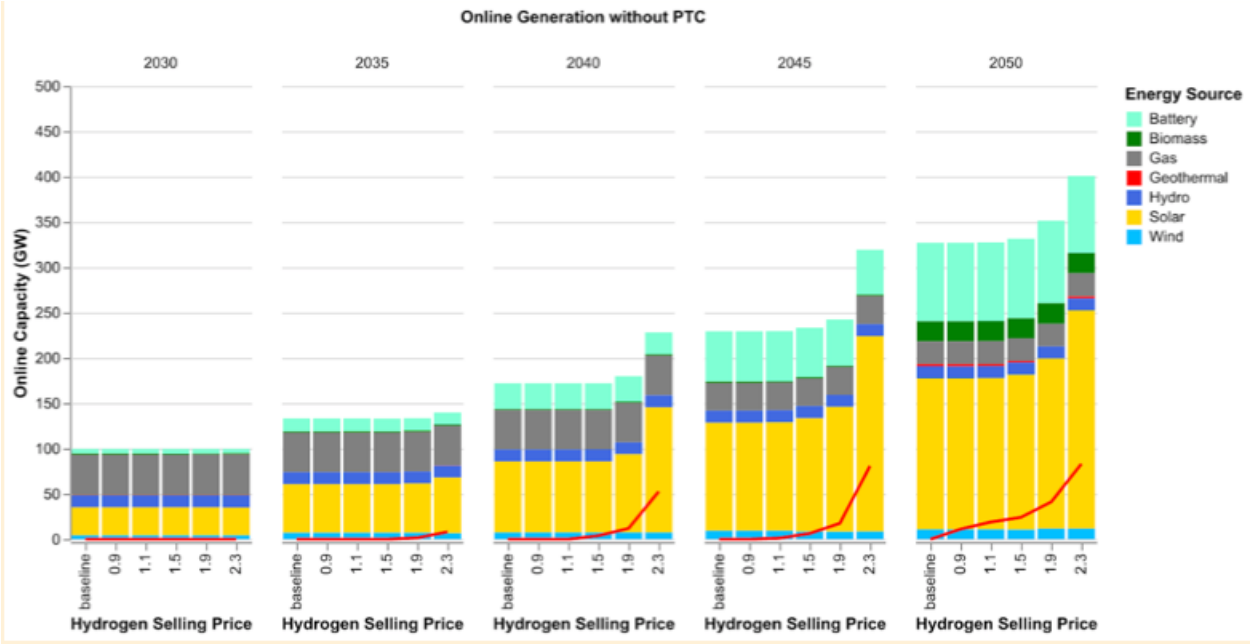

Fig. 6 Online capacity without the green hydrogen production tax credit

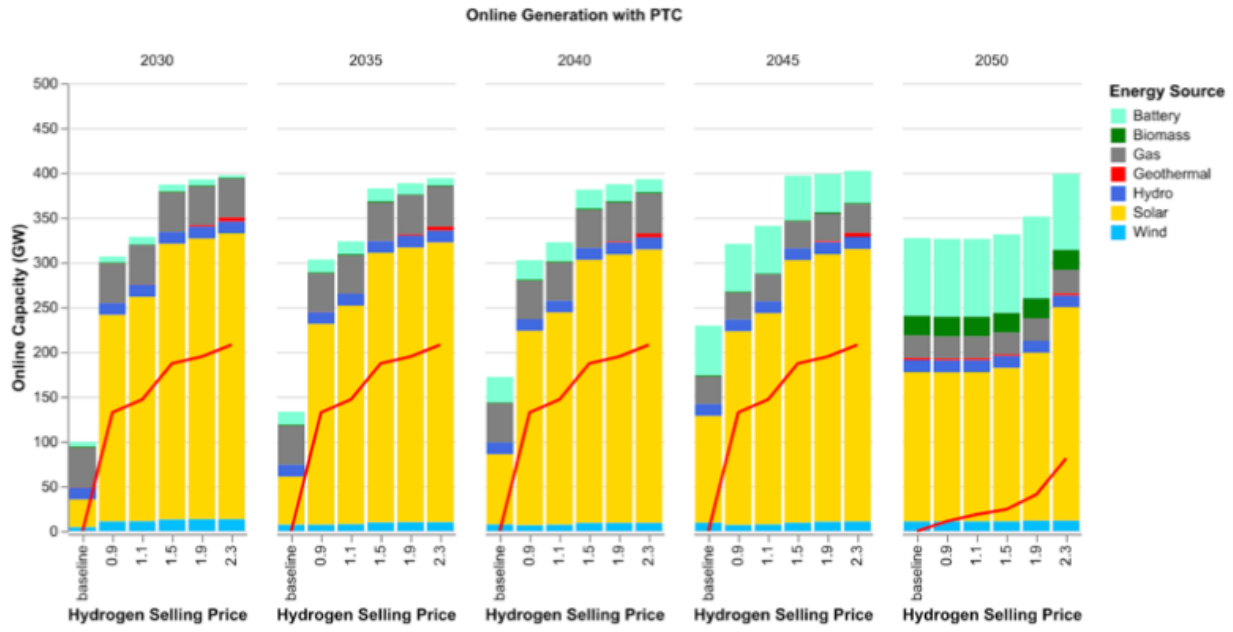

Fig. 7 Online capacity with the green hydrogen production tax credit

The build out of solar and electrolyzers in 2030 impressive, and impractical, but shows the potential of the tax credit to speed adoption. The online capacities in 2050 are less than in 2045 in Fig. 7 because the huge deployments of solar and electrolyzers installed in 2030 have reached their end of life and are retired in 2050. In practice, we wouldn't have all of them retiring at the same time, but the general trend could happen if the incentive is large and then ends abruptly. To fully capture the benefit of the production tax credit, we should estimate the learning that would result

from the enthusiastic deployments in the 2030 time frame and adjust the inputs of the model to benefit from the lower costs in 2050.

This work is being done by Tyler Lis at the University of California Berkeley and will be wrapped up soon as Tyler is finishing this month.

6. *We will prepare to begin to prepare for the public workshop in June and for the draft outline of the final report which is due at the end of June*

Although this discussion occurred in May, it is useful to summarize our recent discussion in response to listening to the E3 public workshop. It is important to think about how our results will be used by those who are hearing them.

As we identify key points to present in the final workshop, we recognize that we should focus on results that will be useful to the California Energy Commission. In the previous workshops we have shown our approaches to understanding how to model long-duration energy storage so that we accurately capture its value across all time scales. Important questions remaining to be answered include:

Diurnal long-duration energy storage:

• For diurnal applications, what is the range of durations that is most effective in competing with a typical 4-h Lithium battery?

• How is this range of durations affected by cost and efficiency?

• How is this range affected by the EV charging profiles?

• How is this range affected by the solar and wind generation profiles?

• How is this range affected by using imports and exports?

Seasonal (including multi-day) long-duration energy storage:

• How will the implementation of electrolyzers for hydrogen generation affect the need for long-duration energy storage?

• How low does the cost of long-duration energy storage need to be for it to replace overbuild of solar (with associated curtailment)?

• How is long-duration energy storage affected by the adoption of generators that give more generation during the winter?

• How is the adoption of seasonal long duration energy storage affected by using imports and exports?

How we are doing compared to our plan

Our final scenario is now defined, and we are generating results now. In discussions with our manager, we have agreed to delay the final workshop.

Significant problems or changes

The invoicing is still behind, but we are now working on the invoice through April 2023. We now have matching funds (cost share) reported for all subcontractors.

What we expect to accomplish during the next period

1. We will continue to meet with stakeholders and community representatives to gather inputs and request feedback
2. We will extend our calculations on the effects of variable solar profiles to include multiple long-duration energy storage options
3. We will complete a first draft of a paper describing the effect of the EV charging profiles on the need for energy storage
4. We will complete a first draft of a paper about the potential effect of oxycombustion on the need for long-duration energy storage
5. We will revise a draft of a paper about the opportunity for hydrogen generation.
6. We will discuss the draft list of questions in section 6 both amongst our team members and with our manager in preparation for presenting a clear set of conclusions at the final public workshop.

Status of Milestones and Products. (highlighted dates need to be modified still)

Task #	Task	Deliverable	Due date	Status
1.2	Kick-off meeting	Updated budget	9/18/2020	Complete
1.3	CPR Meeting #1	CPR Meeting #1	TBD	
	CPR Meeting #2	CPR Meeting #2	1/21/22	Complete
	CPR Meeting #3	CPR Meeting #3	2/16/23	Complete
1.4	Final meeting	Final Meeting	11/11/23	
		Schedule for closeout	11/17/23	
		Draft and Final Written Products	11/17/23	
1.5	Progress Reports & Invoices	Progress Reports	Monthly	Ongoing
		Invoices	Monthly	Ongoing
1.6	Final Report	Draft Outline	6/30/23	
		Final Outline	TBD	
		Draft Report	8/30/23	
		Final Report	10/31/23	

		Written Responses to Comments on Draft Report	9/15/23	
1.7	Match funds	Status letter	9/9/20	Completed
1.9	Subcontracts	Final subcontracts	TBD	Completed
1.10	TAC	List of potential members	9/9/20	Completed
		List of TAC members	TBD	Completed
		Documentation of TAC member commitment	TBD	Completed
1.11	TAC Meetings	Draft TAC meeting schedule	10/1/20	Completed
		TAC meeting 1	11/4/20	Completed
		TAC meeting 2	8/5/21	Completed
		TAC meeting 3	8/19/22	Completed
		TAC meeting 4	3/17/23	Completed
		Note, each meeting need multiple actions		
		Final TAC meeting schedule	TBD	Completed
		Draft TAC meeting agenda	TBD	First one completed
		Backup materials	TBD	First one completed
		Final TAC Meeting agenda	TBD	First one completed
		TAC meeting summaries	TBD	First one completed
2.1	Data assembly	Draft baseline description	2/4/21	Completed
		Final baseline description	2/25/21	Completed
2.2	Confirmation of baseline data and approach	Draft modeling approach description	2/4/21	Completed
		Final modeling approach description	2/25/21	Completed
2.3	Implementation of baseline data into models to create initial baseline scenario	Summary of baseline model results	3/23/21	Completed
		CPR Report #1	15 days prior	Completed
3.1	Evaluate and document future energy storage technology alternatives	Draft storage Technology summary	7/2/21	Completed
		Final storage technology summary	12/12/22	Completed

3.2	Define representative future energy storage technology alternatives	Draft proposed storage scenarios summary	6/1/22	Completed
		Final	1/2/23	Completed
3.3	Evaluate and document future energy electricity generation technology alternatives	Draft electricity generation technology summary	8/2/21	Completed
		Final	10/12/22	Completed
3.4	Define representative future electricity generation technology alternatives	Draft proposed electricity generation scenarios summary	4/1/22	Completed
		Final	11/12/22	Completed
4.1	Multi-day model optimization	Summary of multi-day baseline model results	9/2/21	Completed
		CPR #2	**Summer**	Completed
4.2	Grid scenario selection	Draft grid scenario summary	2/8/22	Completed
		Final	3/7/22	Completed
5.1	Preliminary Scenario Analysis	Draft preliminary analysis summary	7/1/22	Completed
		Final	8/26/22	Completed
5.2	Final scenario analysis	Draft final analysis summary (form will be presentation)	6/30/23	
		Final	7/20/23	
6.1	Initial public meetings	Opening workshop presentation materials	11/17/20	Completed
		Northern CA workshop	12/3/20	Completed
		Southern CA workshop	12/3/20	Completed
		Opening workshop summary	1/8/21	Completed
6.2	Public workshop for grid scenario selection	Agenda	11/2/21	Completed
		Presentation materials	11/2/21	Completed
	Public workshop with CEC and TAC to present proposed scenarios		11/16/21	Completed
		Workshop summary	11/23/21 Summarize public comments: 12/17/21	Completed

6.3	Public workshop for preliminary scenario analysis	Agenda	6/3/22	Completed
		Presentation materials	7/1/22	Completed
	Public Workshop with CEC and TAC to present preliminary analysis		7/12/22	Completed
		Workshop summary	8/9/22	Completed
6.4	Public Workshop for Final Scenario Analysis	Agenda	7/27/23	
		Presentation materials	8/17/23	
	Public workshop with CEC and TAC to present final analysis		8/24/23	
		Workshop summary	9/14/23	
7	Evaluation of Project Benefits	Kick-off meeting benefits questionnaire	9/18/20	Completed
		Final meeting benefits questionnaire	8/1/23	
8	Knowledge transfer activities	Draft initial fact sheet	7/23/20	Completed
		Final initial fact sheet	7/30/20	Completed
		Draft final project fact sheet	7/25/23	
		Final project fact sheet	8/1/23	
		Draft knowledge transfer plan	12/31/20	Completed
		Final knowledge transfer plan	2/26/21	Completed
		Draft knowledge transfer report	8/1/23	
		Final knowledge transfer report	10/1/23	