DOCKETED

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Comment Received From: David Edwards
Submitted On: 7/31/2018
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Air Liquide Feedback on Station Capacity Tool

Additional submitted attachment is included below.

July 31, 2018

California Energy Commission
1516 Ninth Street Sacramento, Ca 95814
ATTN: Jennifer Kurtz

RE: 18-HYD-02 Air Liquide Letter regarding Hydrogen Station Capacity Model (HyC) Workshops

Dear Jennifer and Staff:

On behalf of Air Liquide, thank you for the opportunity to submit our comments regarding the HySCapE Beta 1.0 station capacity modeling tool. We agree that an accurate, robust model is needed to meet both CEC and CARB requirements for evaluating station grant proposals and for determining station capacity for LCFS policy rulings and that the HyC model can meet these needs with consideration of our comments below. As a station developer and an owner/operator, it is important that we understand how the model will be used in implementing these decisions and we encourage the continued open and transparent dialog on these processes.

Recognizing the urgency to have feedback to CEC and CARB regarding the tool performance, we have installed and used the tool to model performance of our Anaheim station and provide the following feedback regarding it's applicability. As we have had limited time to use the tool, please recognize that this cannot represent a comprehensive evaluation, but rather a broad overview of our findings and recommendations. A brief summary of our findings include:

1. We believe the tool is sufficiently robust, providing a systematic, predictable and transparent method that scores proposed equipment relative to an ideal case. **As such, HyC should be suitable to meet the anticipated needs of the CEC and industry**.

2. During our beta testing from 7/24/2018 to 7/31/2018, **we identified several problems with parameter inputs, operational limits, and inconsistencies that will need to be corrected before formal release**. These are detailed in the attachment to this letter.

3. Once a final version of the tool is released, **we recommend a comprehensive evaluation of the existing operating stations in the CEC grant funding program**. Such an evaluation would provide station developers with a baseline for evaluating future station designs prior to proposal or project initiation. We anticipate that such a validation program could be completed before the next CEC grant proposal solicitation.

While we have not had sufficient time to a comprehensive evaluation of the tool against our designs, we hope that the attached evaluation of our Anaheim station provides useful feedback for continued model improvements.

If you have any questions or comments, please contact me at any time.

Sincerely,

David P. Edwards, PhD
Director, Hydrogen Energy
Air Liquide
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MODELING RESULTS – The following is a synopsis of our model testing, in sequence of testing:

1) Anaheim "As Submitted" to NREL

On 4 June 2018, NREL requested that Air Liquide provide information regarding the Anaheim station. Air Liquide responded on 11 June 2018 to this request with the following information:

Component	Variable	Value	Units	Description
electrolyzer	effElyzr		kWh/kg	Electrolyzer efficiency
storage	VhpBank	4.16	m3	Volume high pressure (HP) bank %HITRF: 0.342925
storage	VmpBank	2.03	m3	Volume medium pressure (MP) bank %HITRF: 1.3224;
storage	VlpBank	2.88	m3	Volume low pressure (LP) bank %Default: 2.6108;
storage	VlqBank		m3	Volume of liquid (LQ) bank (22.7125 = 6000 gallons)
storage	numHPbanks	1	#	Number of HP banks
storage	numMPbanks	1	#	Number of MP banks
storage	numLPbanks	1	#	Number of LP banks %12
storage	numLQbanks	0	#	Number of liquid banks
storage	PhpBankMin	70	Mpa	Minimum HP bank pressure (Must use whole numbers or adjust pressure lookup function, Must adjust dispensing algorithm if min Php is less than or equal to 0)
storage	PmpBankMin	20	MPa	Minimum MP bank pressure (Must use whole numbers or adjust pressure lookup function, Must adjust dispensing algorithm if min Pmp is less than or equal to 0)
storage	PlpBankMin	3	MPa	Minimum LP bank pressure
storage	PhpBankMax	82	MPa	Maximum HP bank pressure
storage	PmpBankMax	53	MPa	Maximum MP bank pressure
storage	PlpBankMax	53	MPa	Maximum LP bank pressure
storage	PvapStart		MPa	Vaporizer output pressure (must be greater than MP compressor minimum) (www.linde-engineering.com.hk/internet.le.le.hkg/zt/images/P_3_4_e_10_150dpi227_5776.pdf?v=.)
storage	hpDispense	1	logical [0,1]	Eligible for fill, 1=eligible, 0=not eligible
storage	mpDispense	0	logical [0,1]	Eligible for fill, 1=eligible, 0=not eligible
compressor	NumHPc	1	#	Number of high pressure compressors
compressor	NumMPc	1	#	Number of medium pressure compressors
compressor	PminHPc	20	MPa	(unused) Minimum High pressure compressor (HPc) pressure

compressor	PminMPc	0.5	MPa	(unused) Minimum Medium pressure compressor (MPc) pressure
compressor	PmaxHPc	90	Mpa	(unused) Maximum HPc pressure
compressor	PmaxMPc	40	Mpa	(unused) Maximum MPc pressure
compressor	Fhp1	216	kg/h	HPc maximum flowrate
compressor	Fmp1	25	kg/h	MPc maximum flowrate
compressor	Flq1		kg/h	Liquid pump maximum flowrate
compressor	Fvap1		kg/h	Vaporizer maximum flowrate
compressor	effHP		kWh/kg	HPc efficinecy (includes BOP)
compressor	effMP		kWh/kg	MPc efficiency (includes BOP)
precooling	setPointPC	-37	degC	(unused) Pre-cooling setpoint
precooling	effPC		kWh/kg	Pre-cooling efficiency
precooling	powerPC	60	kW	fixed Pre-cooling power
precooling	recTimePC		s	(unused)
dispenser	Fdisp		kg/s	Dispenser flow rate
dispenser	staTemp		degC	Ambient temperature
dispenser	max_disp		#	Maximum number of dispensers
delivery	startMassDel	108	kg	Mass per delivery
delivery	numDeliveries	1	#/day	Number of deliveries per day
delivery	numBanksDel	0	#	Number of banks delivering hydrogen
delivery	Pdel	45	MPa	Pressure of delivery truck
delivery	Fdel	0	kg/s	(unused) Delivery flow rate
delivery	Del_wait_time	2700	s	Delivery truck dwell time
delivery	Delivery_type	1	selector [1,2]	Fuel delivery type, 1=gaseous, 2=liquid
liquid	FlqTruck		kg/s	Liquid truck delivery rate to storage
liquid	effPmpLQ		kWh/kg	Liquid pump efficiency (kWh/kg of station capacity) (HRSAM v1.1)
liquid	effRef		kWh/kg	Refrigeration efficiency (HRSAM v1.1) (is this more representative as a constant (kW/s) or as specific energy consumption (kW/kg/s)
liquid	BoilOff		kg/day	Boil-off (HRSAM v1.1 for 200kg/day capacity station) (Not wired up yet, consider calculating boil-off based on physical properties)
liquid	effVAP		kWh/kg	Vaporizer efficiency (HRSAM, Evaporator heated by natural draft so no effect)

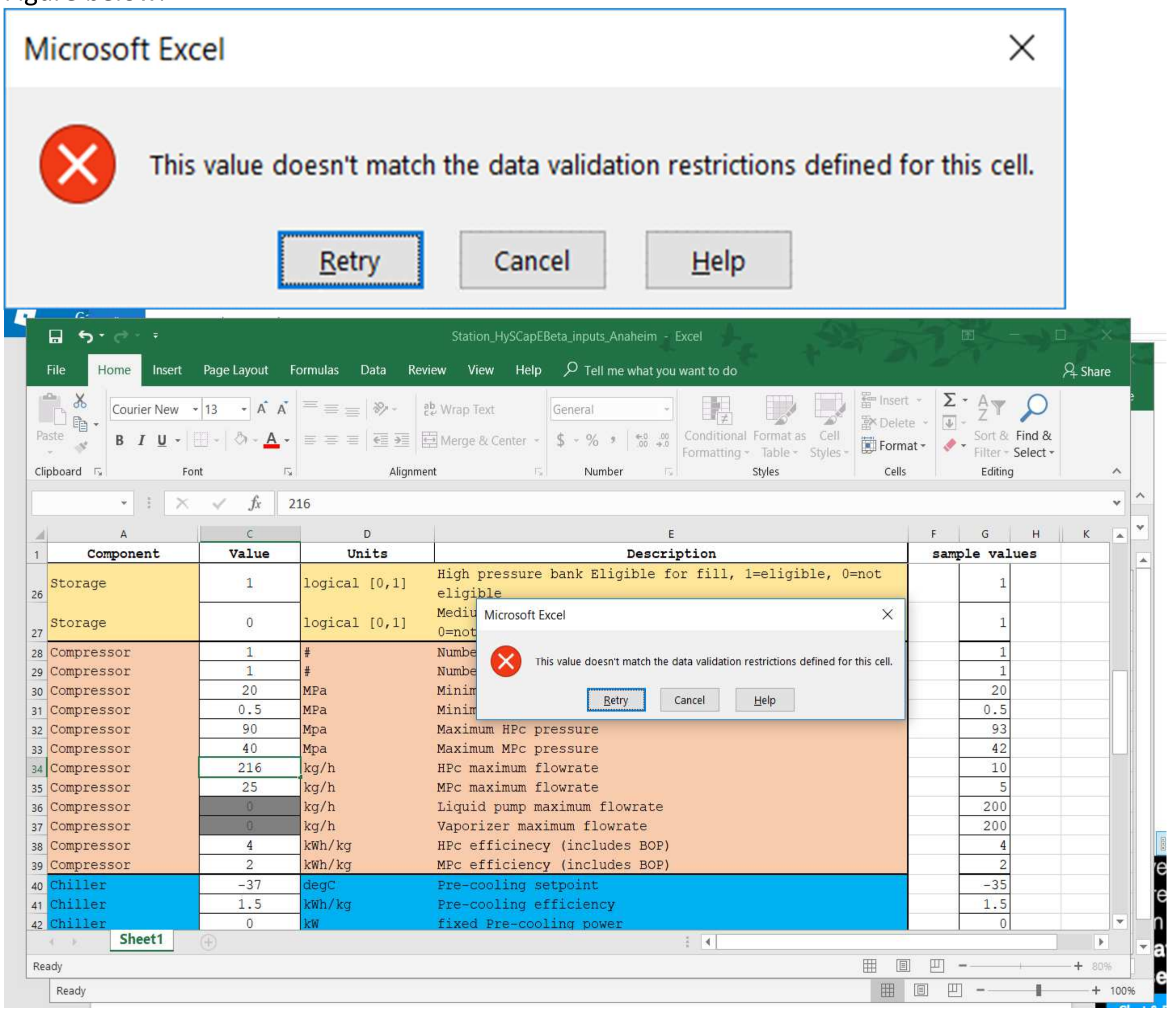
The HySCapE model was made available through the CEC Docket 18-HYD-02 on 7/24/2018 around noon, pacific time.

Air Liquide was unable to install the model onto corporate computers due to corporate security concerns, therefore all testing occurred on employee’s personal computers.

Recommendation #1 Develop a Web Interface to the Executable – The model as an executable file presents barriers to use by corporate stakeholders as corporate IT departments are unwilling to allow installation of an executable file from a 3rd party, particularly when it is described as 'beta testing'. Approval process of 3-5 days is common. NREL and CEC suggested that the tool might be available as a website portal, such a website could be beneficial but would expose user's proprietary designs to the website host. Perhaps NREL might consider use of a secure cloud server with individual login and access for each stakeholder?

The installation on personal computers was smooth and instructions were easy to follow.

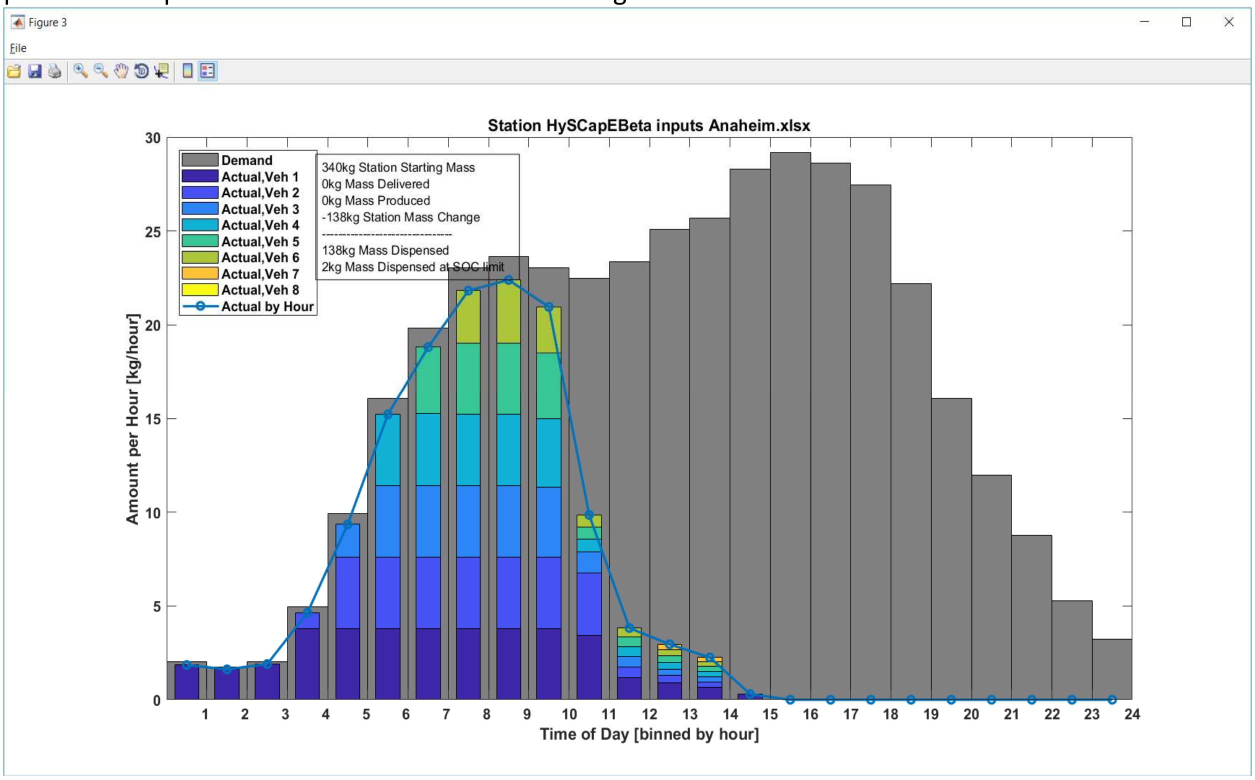
Air Liquide attempted to use the inputs shown in Table 1 above. One of the values, "Fhp1" , the flowrate of the high pressure compressor was not allowed. HySCapE provided the error shown in the Figure below.



Recommendation #2 HP Compressor Limit – Air Liquide uses a high pressure compressor configuration which allows for 216 kg/h (60 g/sec). It is not clear why HySCapE limits the high pressure compressor to 100 kg/h as a maximum input value. This limitation is a barrier to station equipment designs using a high throughput high pressure compressor.

Iteration of this value revealed that 100 kg/h is the maximum allowable input. Thus the remaining iterations for Anaheim were conducted with the maximum value of 100 kg/h as the high pressure compressor flowrate.

The first successful calculation revealed an incorrect value was provided to NREL by Air Liquide. The maximum pressure of the HP buffer was provided as 82 MPa. Thus the first successful calculation provided the profile and net results shown in the Figure below.

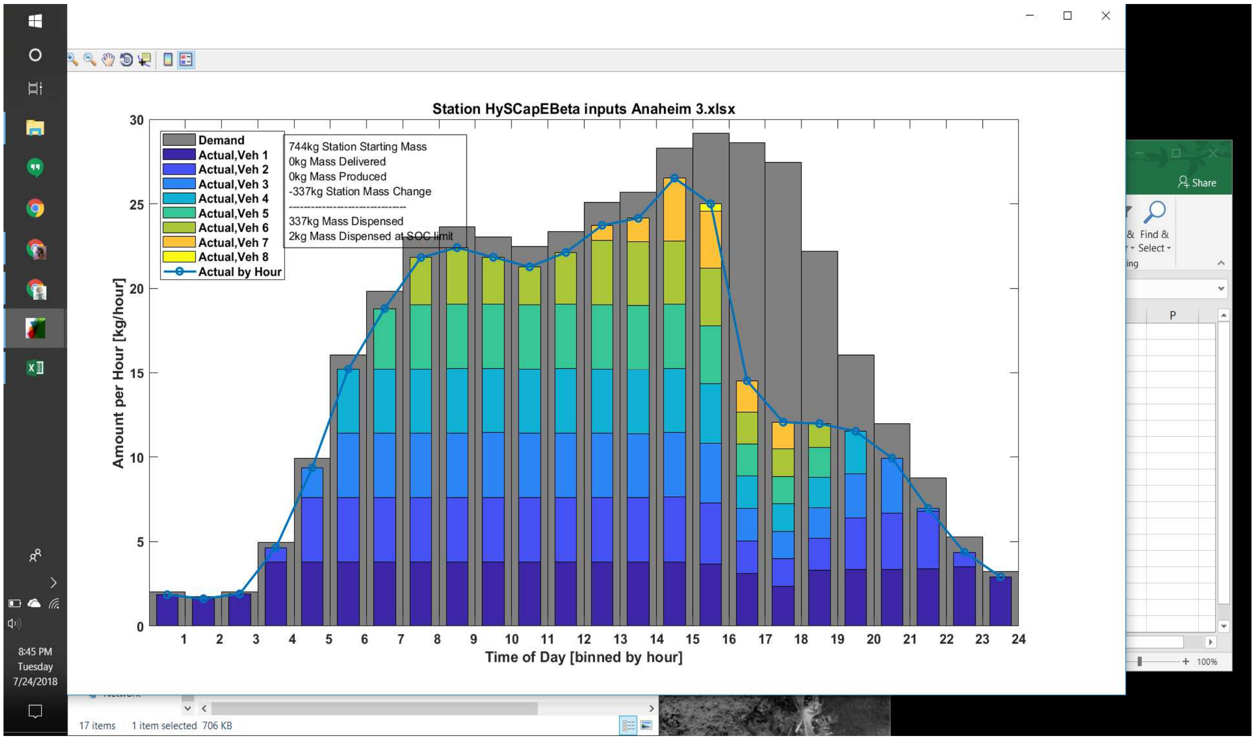


It was clear that an input error occurred as the Mass dispensed is predicted as 138 kg but only 2 kg of mass are dispensed at the SOC.

The second calculation in HySCapE increased the number of deliveries to 2. This calculation was conducted to ensure that the delivery module was not functioning. It was unclear from the documentation and the presentations if the delivery module would be implemented. Results for the section calculation were identical to the first calculation.

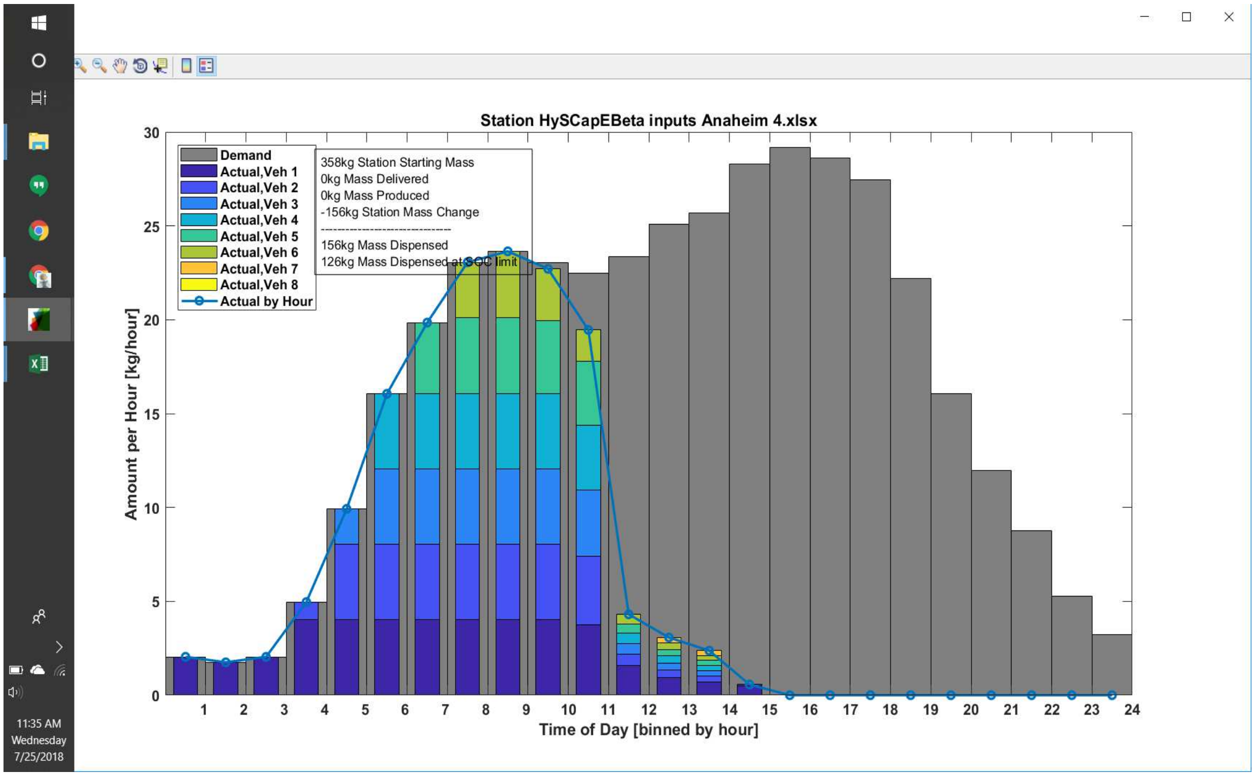
Recommendation #3 Implementation of the Delivery Module – The lack of a delivery module in HySCapE leads to the significant underestimate of station capacity. Without the delivery module, the program results are subject to a high degree of uncertainty.

The third calculation in HySCapE considered a significantly larger LP buffer volume, consistent with a 'trailer swap' station. The LP buffer value was changed from 2.88 cubic meters to 15 cubic meters with all other variables the same as the first and second calculations. The result is shown below in the Figure below.



This result appeared consistent with the theoretical capacity of Anaheim, were a high pressure (50MPa) trailer to remain on site in place of the existing LP buffer storage. Again, this result also highlighted the issue mentioned previously regarding the error in Air Liquide's information supplied to NREL initially, which mistakenly listed the HP buffer maximum pressure as 82 MPA. Thus the third calculation predicts 337 kg mass dispensed but still only 2 kg at SOC.

The fourth calculation in HySCapE a correction on the input for HP buffer maximum pressure, 95 MPa for second calculation. The results profile is shown in figure ## below. The change in this maximum HP buffer pressure has a significant impact on the kg dispensed at SOC. This value increases from 2 kg to 126 kg.

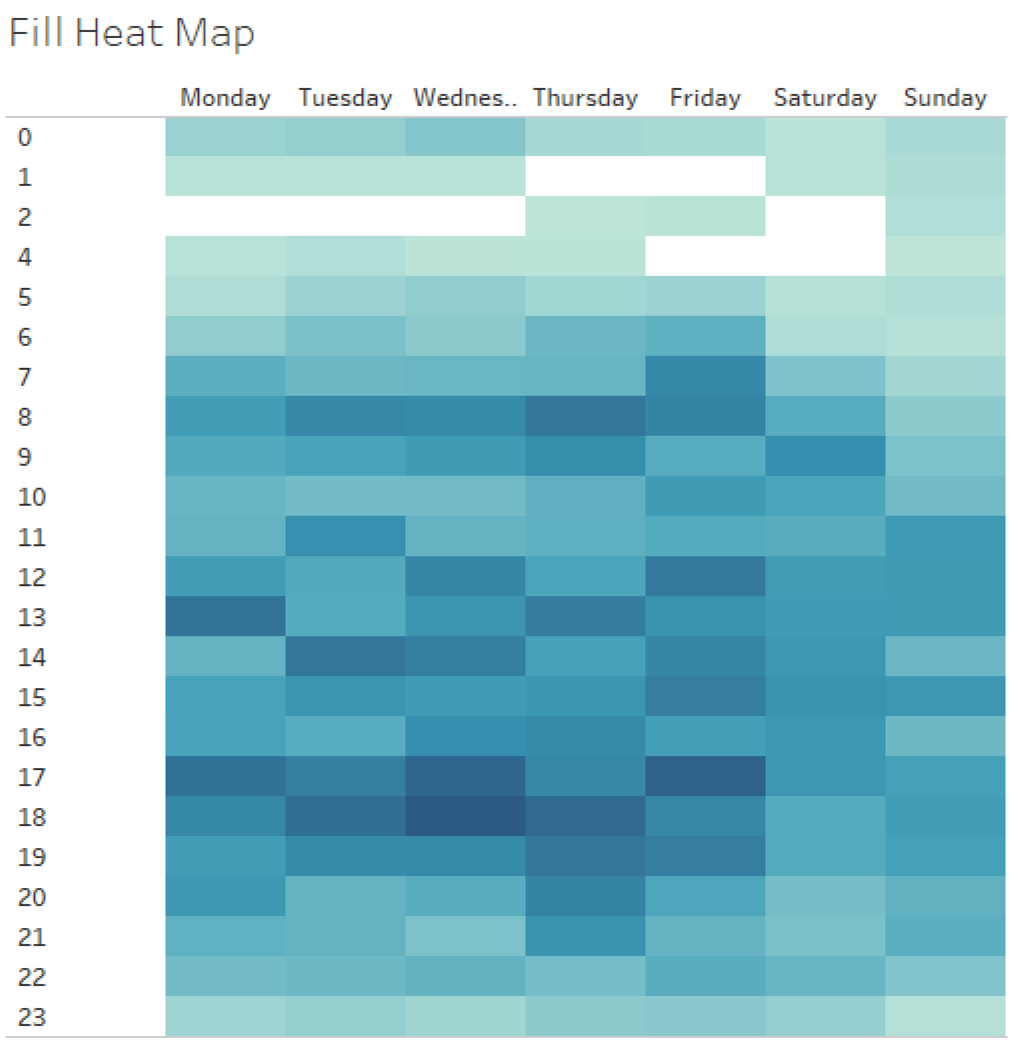


Recommendation #4 Modify the HP Cascade Process - The use of the HP buffer maximum as the cascade pressure to the vehicle is inaccurate. The actual pressure provided in the dispenser is limited to 87.5 MPa under NFPA 2. Since this is a prescribed limit, Air Liquide, consistent with good practice for controls systems sets software control limits at a pressure less than 87.5 MPa. Thus HySCapE fueling algorithm should be verified for accuracy with actual performance.

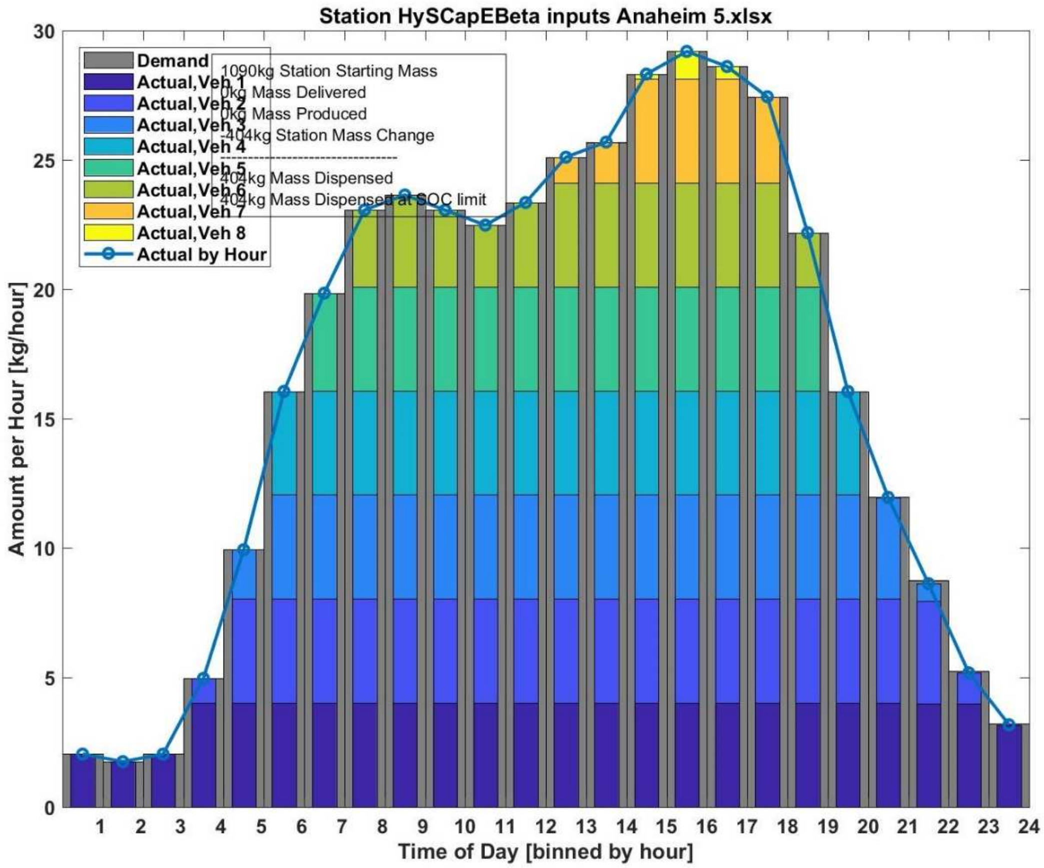
This fourth calculation is consistent with Anaheim performance. The HySCapE predicts 156 kg mass dispensed and 126 kg dispensed at SOC. Actual values for Anaheim are shown in the Table below.

	Avg Fills per day	Avg kg Disp per day	Avg SOC Achieved per week
Week starting 5/28/2018	49.7	147	96.6
Week starting 6/4/2018	55.4	165	97.2
Week starting 6/11/2018	38.6	112	96.7
Week starting 6/18/2018	49.7	151	97.4
Week starting 6/25/2018	53.4	169	97.6
Week starting 7/2/2018	48.4	146	97.9
Week starting 7/9/2018	60.6	172	96.3
Week starting 7/16/2018	53.7	146	94.6

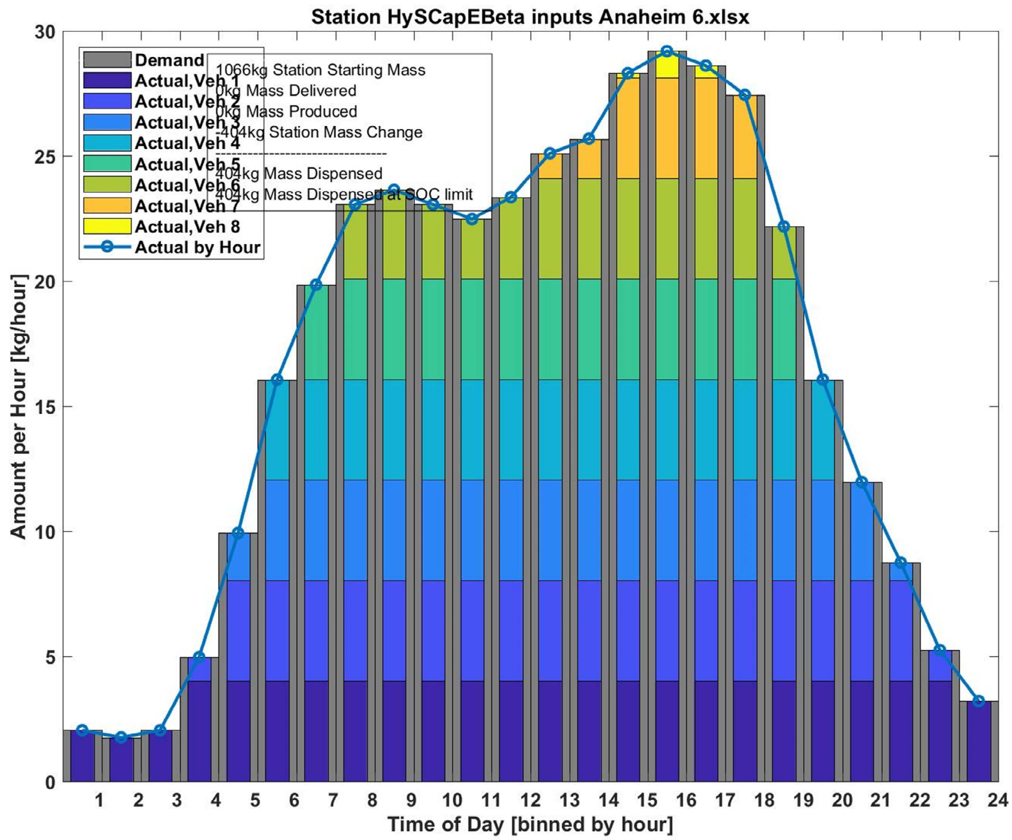
Observation: Effect of the Chevron Profile - HySCapE accurately predicts the daily performance at Anaheim although the actual profile varies somewhat from the actual experience. A "heat map" for Anaheim is provided below and demonstrates a somewhat variable pattern with heaviest demand in the later evening. Of course the Chevron profile is a composite of hundreds of gas stations vs. one hydrogen fueling position.



Calculation # 5 – set storage to very high level and iterated to find the maximum influencing compressor throughput ~ 35 kg/h for both MP and HP compressors



Calculation #6 – minimized storage on gaseous system to determine the minimum required to match the "Chevron Friday" profile. Requires ~ 1060 kg storage to dispense 404 kg.



Observation Regarding Site Storage – When comparing the ratio of the overall site storage ("Station starting Mass") to the mass dispensed there is a range of ratios for otherwise optimized systems. Ratios range from 2.2 to 2.6. This indicates that equipment which is optimized to the capacity desired should attempt to score within this ratio. Unfortunately the ratio is rather high considering the overall cost estimated for installed capacity. DOE predicts CAPEX cost of $1000/kg for storage. Thus over half of the storage at the station will be un-utilized. It is unclear how that will influence station equipment design and supply chain logistics. CEC and CARB should consider carefully to prevent a barrier to innovation around this ratio.

Recommendation #5 HGV 4.9 Fill - 5kg fills, not 4kg as in HGV 4.9 or the average reported in the NREL CDP