

<b>DOCKETED</b>	
<b>Docket Number:</b>	18-HYD-04
<b>Project Title:</b>	Draft Solicitation Concepts for Light-Duty Hydrogen Refueling Infrastructure
<b>TN #:</b>	229881
<b>Document Title:</b>	September 27 NREL HySCapE Staff Workshop Presentation
<b>Description:</b>	N/A
<b>Filer:</b>	Jessica Martinez
<b>Organization:</b>	California Energy Commission
<b>Submitter Role:</b>	Commission Staff
<b>Submission Date:</b>	9/30/2019 7:18:08 AM
<b>Docketed Date:</b>	9/30/2019

# HySCapE – Hydrogen Station Capacity Evaluation Overview

Sam Sprik, Taichi Kuroki, Jen Kurtz

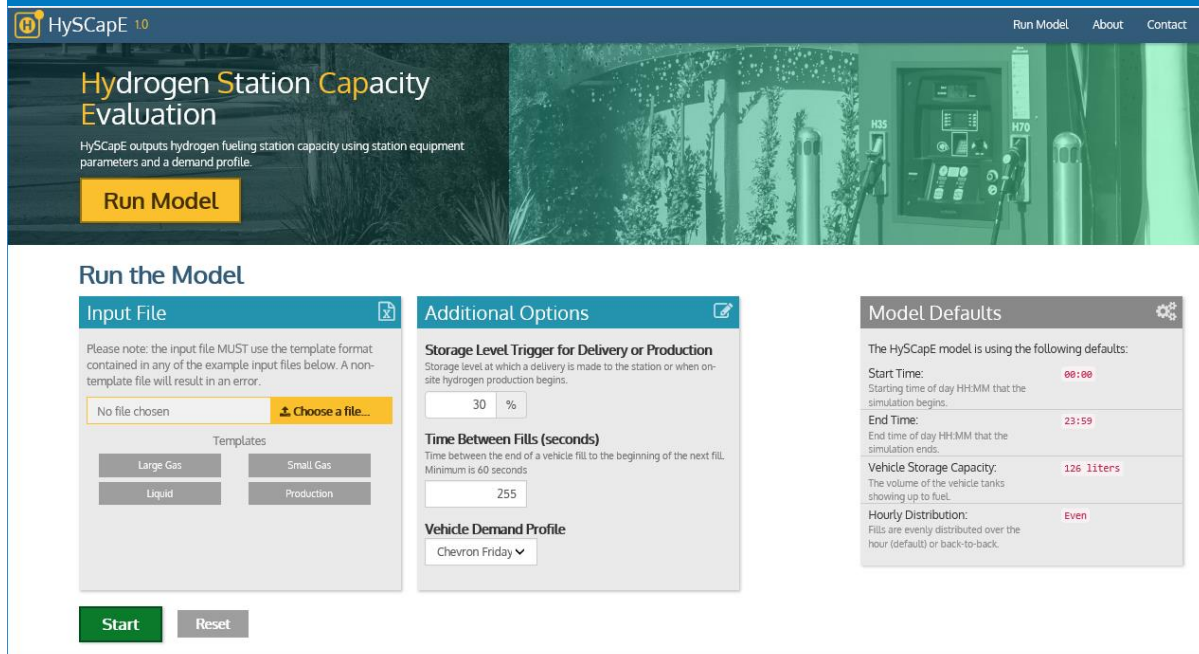
September 27, 2019  
CEC Staff Workshop

# Agenda

- HySCapE overview
  - Web Interface
  - Inputs, Outputs
- Sample Stations
  - Delivered gas
  - Delivered liquid
- Review of Assumptions
- Questions and Answers

# HySCapE 1.0 Web Interface

[openei.org/apps/hyscape](https://openei.org/apps/hyscape)



The screenshot displays the HySCapE 1.0 web interface. At the top, there's a navigation bar with 'Run Model', 'About', and 'Contact' links. The main header area features the title 'Hydrogen Station Capacity Evaluation' and a brief description of the tool's purpose. A prominent 'Run Model' button is visible. Below this, the 'Run the Model' section is divided into three panels: 'Input File', 'Additional Options', and 'Model Defaults'. The 'Input File' panel includes a file selection area and a 'Choose a file...' button. The 'Additional Options' panel contains settings for 'Storage Level Trigger for Delivery or Production' (set to 30%), 'Time Between Fills (seconds)' (set to 255), and 'Vehicle Demand Profile' (set to 'Chevron Friday'). The 'Model Defaults' panel lists default values for 'Start Time' (00:00), 'End Time' (23:59), 'Vehicle Storage Capacity' (126 liters), and 'Hourly Distribution' (Even). At the bottom of the 'Run the Model' section are 'Start' and 'Reset' buttons.

## Run the Model

### Input File

Please note: the input file MUST use the template format contained in any of the example input files below. A non-template file will result in an error.

No file chosen [Choose a file...](#)

Templates

- Large Gas
- Small Gas
- Liquid
- Production

**Start** **Reset**

### Additional Options

#### Storage Level Trigger for Delivery or Production

Storage level at which a delivery is made to the station or when on-site hydrogen production begins.

30 %

#### Time Between Fills (seconds)

Time between the end of a vehicle fill to the beginning of the next fill. Minimum is 60 seconds

255

#### Vehicle Demand Profile

Chevron Friday

### Model Defaults

The HySCapE model is using the following defaults:

<b>Start Time:</b> Starting time of day HH:MM that the simulation begins.	00:00
<b>End Time:</b> End time of day HH:MM that the simulation ends.	23:59
<b>Vehicle Storage Capacity:</b> The volume of the vehicle tanks showing up to fuel.	126 liters
<b>Hourly Distribution:</b> Fills are evenly distributed over the hour (default) or back-to-back.	Even

- Simple to use physics-based tool
- Publicly available
- Calculates dispensing capacity for multiple configurations of hydrogen stations.
- Runs on server over the internet
- Results are output in images and spreadsheet

## About HySCapE

The Hydrogen Station Capacity Evaluation (HySCapE) model is designed to estimate hydrogen station capacity, based on user inputs for the hydrogen station capacity and pre-defined fueling demand profile. HySCapE is a mass balance model with simple, transparent methods for capacity estimation that can be consistently applied for different station configurations. This model is not a design tool or customized for individual station details like control strategy.

HySCapE reads the external user inputs and balances mass every second based on the predefined fueling demand scenario. The capacity calculation utilizes CSA HGV 4.9 [1] as the basis to determine one fill. The model has algorithms for dispensing, compression, delivery, and production. HySCapE outputs the number of kilograms (kg) dispensed in total and for full fills. A full fill is assumed to be greater than or equal to 95% state-of-charge (SOC). The output also includes more details on fill count, amount, duration, ending SOC, and station storage pressures and masses for the user to see how the algorithms were applied.

View the [HySCapE Documentation](#) for more details.

# Input File Selection

## Input File

Please note: the input file MUST use the template format contained in any of the example input files below. A non-template file will result in an error.

SampleStation\_HySCapELarg...

Choose a file...

### Templates

Large Gas

Small Gas

Liquid

Production

Choose input file.  
Excel (.xlsx) file  
with same format  
as template files

Click to download example templates. Modify these using your station parameters.

	Component	Value	Units	Description
1	Delivery	1	logical [0,1]	Gas delivery to station
2	Delivery	0	logical [0,1]	Liquid delivery to station
3	Production	0	logical [0,1]	On-site production at station
4	Storage	1	logical [0,1]	High pressure storage at station
5	Storage	0	logical [0,1]	Medium pressure storage at station
6	Storage	1	logical [0,1]	Low pressure storage at station
7	Production	0	%	Storage level trigger for production
8	Production	0	kWh/kg	Production unit efficiency
9	Production	0	kg/h	flow/production rate
10	Production	0	MPa	output max pressure
11	Storage	0.42	m3	Volume high pressure (HP) bank %HITRF: 0.342925
12	Storage	0	m3	Volume medium pressure (MP) bank %HITRF: 1.3224
13	Storage	3	m3	Volume low pressure (LP) bank %Default: 2.6108
14	Storage	0	m3	Volume of liquid (LQ) bank (22.7125 = 6000 gallons)
15	Storage	4	#	Number of high pressure banks
16	Storage	0	#	Number of medium pressure banks
17	Storage	9	#	Number of low pressure banks
18	Storage	0	#	Number of liquid banks
19	Storage	45	Mpa	Minimum HP 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)
20	Storage	0	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)
21	Storage	0	MPa	Minimum LP bank pressure
22	Storage	90	MPa	Maximum HP bank pressure
23	Storage	0	MPa	Maximum MP bank pressure
24	Storage	50	MPa	Maximum LP bank pressure
25	Storage	0	MPa	Vaporizer output pressure (must be greater than MP compressor minimum) (v.v.v. Inde- engineering.com.hk/Internet.le.le.hig/ztimages/P_3_4_e_10_150d pi227_5776.pdf?v=)
26	Storage	1	logical [0,1]	High pressure bank Eligible for fill, 1=eligible, 0=not eligible
27	Storage	0	logical [0,1]	Medium pressure bank Eligible for fill, 1=eligible, 0=not eligible
28	Storage	1	logical [0,1]	Low pressure bank Eligible for fill, 1=eligible, 0=not eligible
29	Compressor	1	logical [0,1]	Allow compressor to fill bank which are used for dispensing?, 1=yes, 0=no
30	Compressor	1	#	Number of high pressure compressors
31	Compressor	0	#	Number of medium pressure compressors
32	Compressor	5	MPa	Minimum High pressure compressor (HPo) pressure
33	Compressor	0	MPa	Minimum Medium pressure compressor (MPo) pressure
34	Compressor	90	Mpa	Maximum HPo pressure
35	Compressor	0	Mpa	Maximum MPo pressure
36	Compressor	0	kg/h	HPo maximum flow rate

# Additional Input Options

**Additional Options**

**Storage Level Trigger for Delivery or Production**  
Storage level at which a delivery is made to the station or when on-site hydrogen production begins.

30 %

**Time Between Fills (seconds)**  
Time between the end of a vehicle fill to the beginning of the next fill.  
Minimum is 60 seconds

255

**Vehicle Demand Profile**

Chevron Friday

Storage level trigger for delivery or production. Model assumes the station is full at start of run.

Time between fills value sets max possible fills in the peak fueling hour (e.g., 3-4 pm Chevron Friday), which then determines 24-hour capacity.

Demand profile selection

**Vehicle Demand Profile**

Chevron Friday

Chevron Friday


1 Hour

3 Hour

1 Hour and 3 Hour – These are max effort based on time between fills and the average 1kg/min fueling rate.

# Model Defaults (Displayed on Web Interface)

## Model Defaults



The HySCapE model is using the following defaults:

Start Time: Starting time of day HH:MM that the simulation begins.	00:00
End Time: End time of day HH:MM that the simulation ends.	23:59
Vehicle Storage Capacity: The volume of the vehicle tanks showing up to fuel.	126 liters
Hourly Distribution: Fills are evenly distributed over the hour (default) or back-to-back.	Even

Starts at midnight

Runs for 24 hours.

Vehicle Storage Capacity is fixed at 126 liters (~5 kg at 70MPa)

**Even hourly distribution**  
Fills are spread out over each hour instead of back-to-back from beginning of hour.

# Running HySCapE 1.0

## Run the Model

Input File

Please note: the input file MUST use the template format contained in any of the example input files below. A non-template file will result in an error.

SampleStation\_HySCapELarg... 

Choose a file...

Templates

Large Gas

Small Gas

Liquid

Production

Start

Reset

## Processing Results...

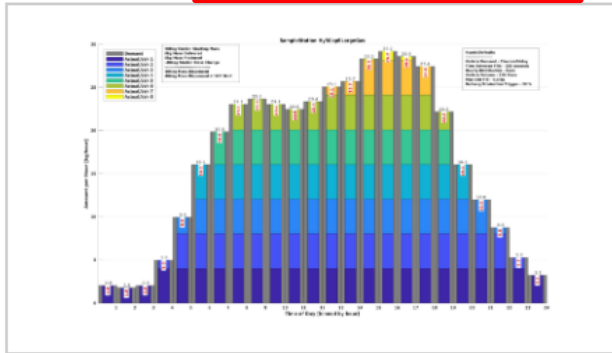
HySCapE may take up to 2 minutes to process. **Please do not refresh your browser.**



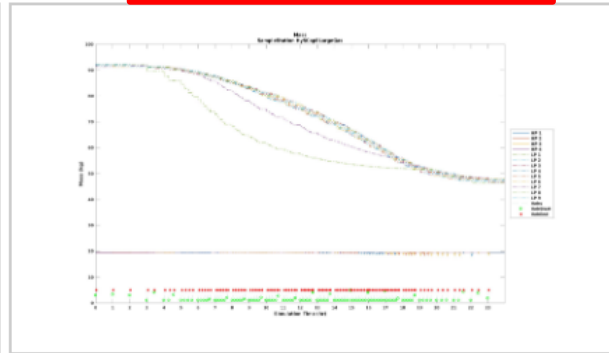
# Results Screen

## Results

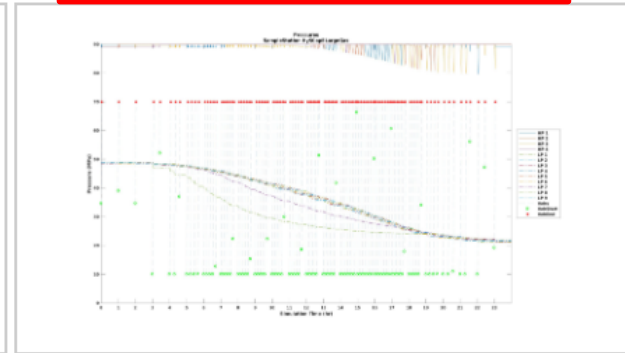
### Hourly Dispensed



### Mass over 24 hours




### Pressures over 24 hours



Output.xlsx

### Data Results

 Download All

# Large delivered gas Inputs

Component	Value	Units	Description
Production	0	kg/h	flow/production rate
Production	0	MPa	output max pressure
Storage	0.42	m3	Volume high pressure (HP) bank %HITRF: 0.342925
Storage	0	m3	Volume medium pressure (MP) bank %HITRF: 1.3224;
Storage	3	m3	Volume low pressure (LP) bank %Default: 2.6108;
Storage	0	m3	Volume of liquid (LO) bank (22.7125 = 6000 gallons)
Storage	4	#	Number of high pressure banks
Storage	0	#	Number of medium pressure banks
Storage	9	#	Number of low pressure banks
Storage	0	#	Number of liquid banks
Storage	45	Mpa	Minimum HP bank pressure (Must use whole numbers or adjust pressure lookup function, Must adjust dispensing algorithm if min P <sub>hp</sub> is less than or equal to 0)
Storage	0	MPa	Minimum MP bank pressure (Must use whole numbers or adjust pressure lookup function, Must adjust dispensing algorithm if min P <sub>mp</sub> is less than or equal to 0)
Storage	0	MPa	Minimum LP bank pressure
Storage	90	MPa	Maximum HP bank pressure
Storage	0	MPa	Maximum MP bank pressure
Storage	50	MPa	Maximum LP bank pressure
Storage	0	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	1	logical [0,1]	High pressure bank Eligible for fill, 1=eligible, 0=not eligible
Storage	0	logical [0,1]	Medium pressure bank Eligible for fill, 1=eligible, 0=not eligible

Volume of 1 HP bank

# of HP banks

Min Pressure

Max Pressure

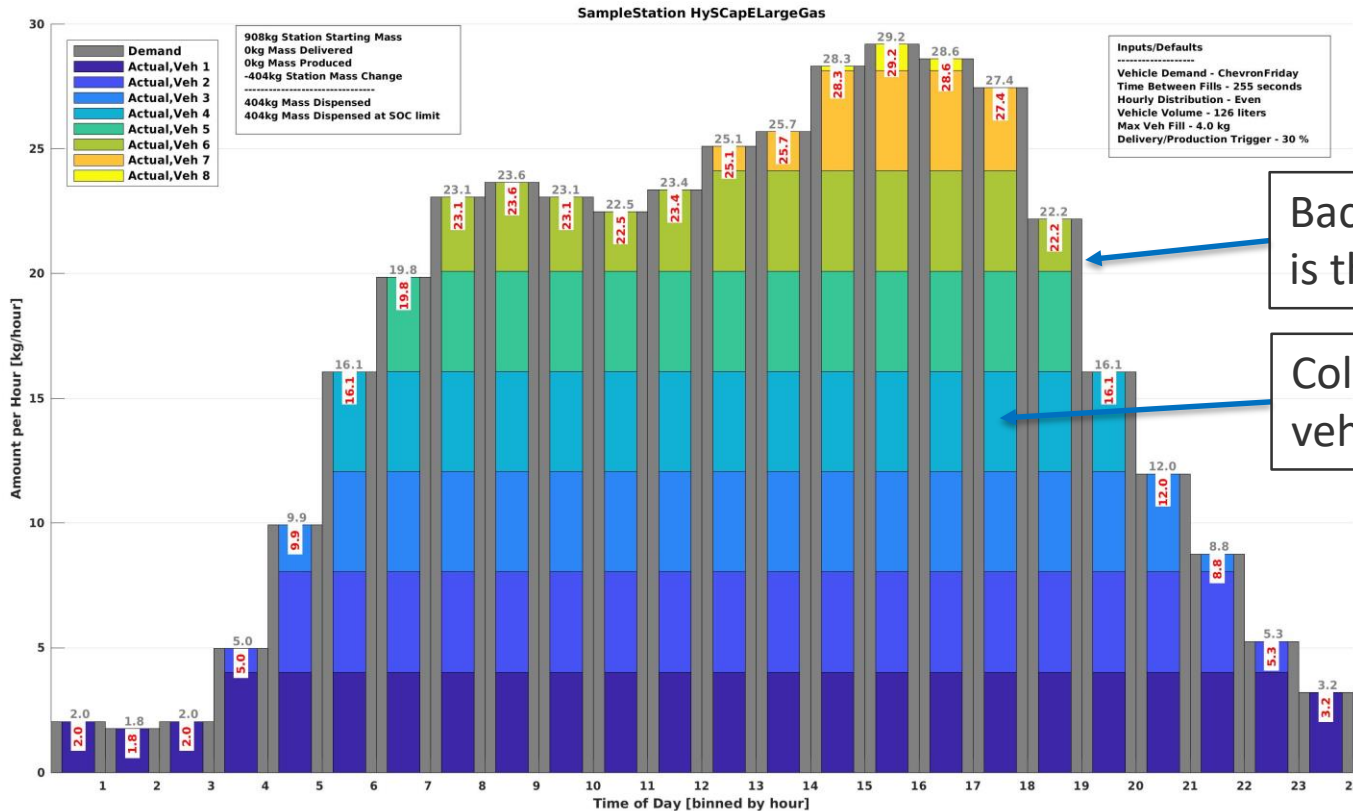
# Large delivered gas *Inputs*

Component	Value	Units	Description
Storage	0	MPa	Minimum LP bank pressure
Storage	90	MPa	Maximum HP bank pressure
Storage	0	MPa	Maximum MP bank pressure
Storage	50	MPa	Maximum LP bank pressure
Storage	0	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	1	logical [0,1]	High pressure bank Eligible for fill, 1=eligible, 0=not eligible
Storage	0	logical [0,1]	Medium pressure bank Eligible for fill, 1=eligible, 0=not eligible
Storage	1	logical [0,1]	Low pressure bank Eligible for fill, 1=eligible, 0=not eligible
Compressor	1	logical [0,1]	Allow compressor to fill bank which are used for dispensing?, 1=yes, 0=no.
Compressor	1	#	Number of high pressure compressors
Compressor	0	#	Number of medium pressure compressors
Compressor	5	MPa	Minimum High pressure compressor (HPc) pressure
Compressor	0	MPa	Minimum Medium pressure compressor (MPc) pressure
Compressor	90	Mpa	Maximum HPc pressure
Compressor	0	Mpa	Maximum MPc pressure
Compressor	75	kg/h	HPc maximum flowrate
Compressor	0	kg/h	MPc maximum flowrate
Compressor	0	kg/h	Liquid pump maximum flowrate
Compressor	0	kg/h	Vaporizer maximum flowrate
Dispenser	20	°C	Ambient temperature
Dispenser	1	#	Maximum number fueling positions capable of simultaneous fill
Delivery	300	kg	Mass per delivery
Delivery	1	#/day	Number of deliveries per day
Delivery	6	#	Number of banks delivering hydrogen
Delivery	35	MPa	Pressure of delivery truck
Delivery	1	kg/s	Delivery flow rate
Delivery	3600	s	Delivery truck dwell time
Delivery	1	selector [1,2]	Fuel delivery type, 1=gaseous, 2=liquid
Liquid	0	kg/s	Liquid truck delivery rate to storage

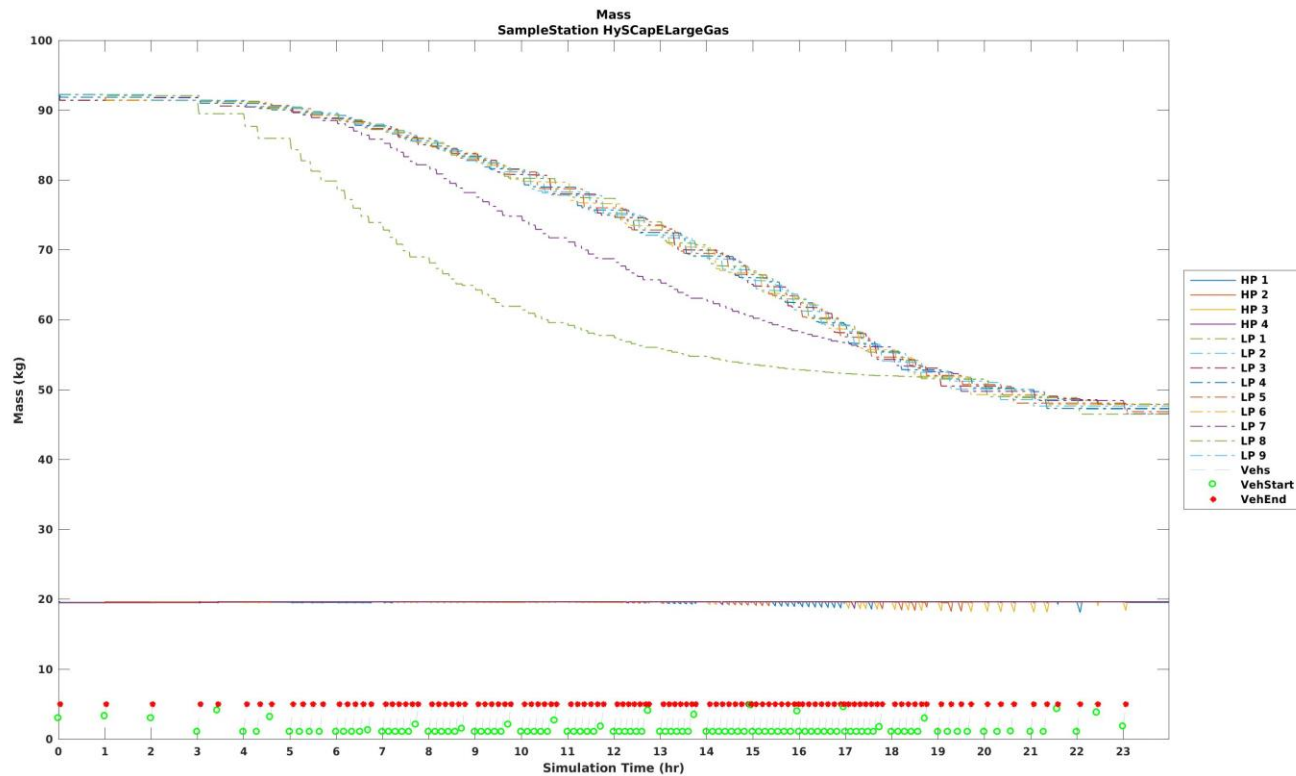
Allow compression into bank that is simultaneously dispensing

# of simultaneous fueling positions. Entry of 2 doubles the demand at the station

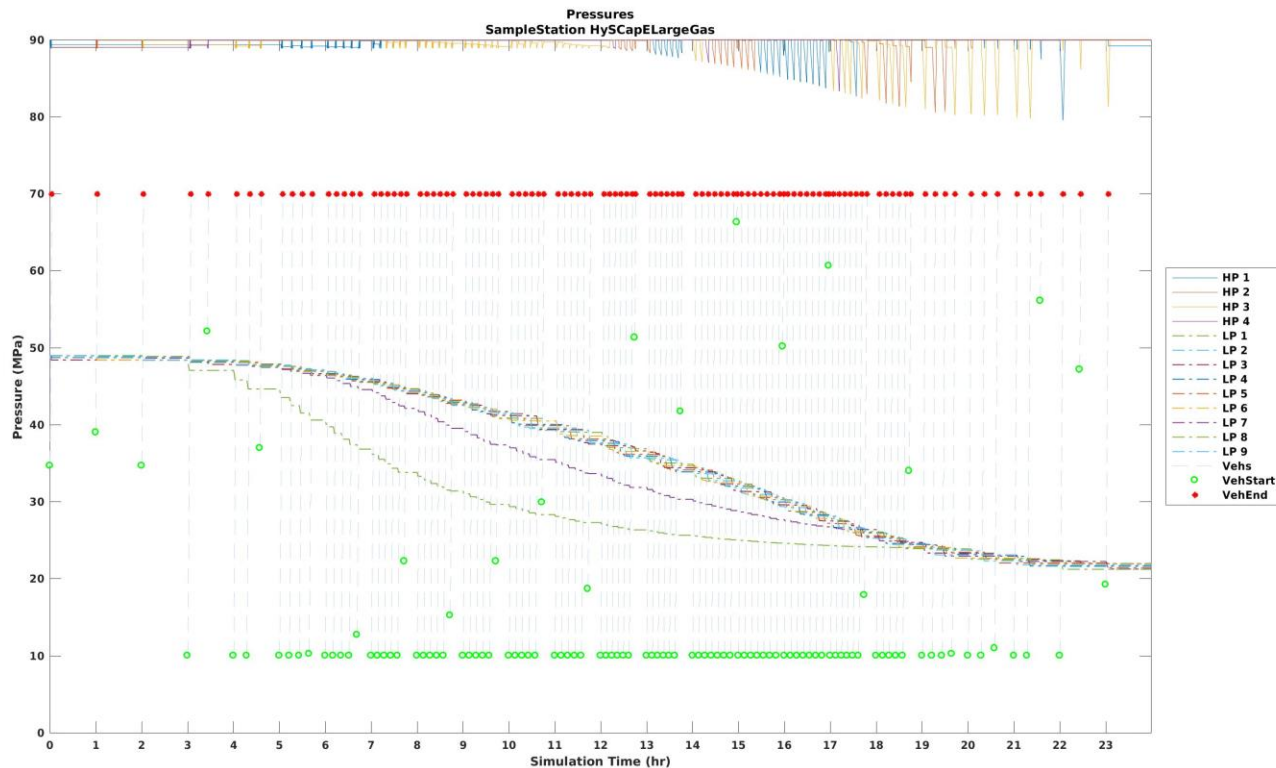
# Large delivered gas - *Fill Profile*



# Large delivered gas *Storage/Dispense Mass*



# Large delivered gas *Storage/Dispense Pressures*



# Large delivered gas *Output .xlsx file*

	A	B	C	D	E
1	C1	C2	C3	C4	C5
2	Input File	SampleStation_HySCapELargeGas_inputs.xlsx			
3	Output File	outfile.xlsx			
4	Vehicle Demand	ChevronFriday			
5	Hourly Distribution	Even			
6	Time Between Fills	255	seconds		
7	Vehicle Volume	126	liters		
8	Delivery Trigger	30	%		
9	Variable	Value	Units	Description	
10	Starting Mass	908.2971318	kg	station starting mass	
11	Ending Mass	504.3135562	kg	station ending mass	
12	Total H2 Dispensed	403.9835756	kg	sum of hydrogen dispensed	
13	H2 Dispensed to SOC Limit	403.9835756	kg	sum of hydrogen dispensed that meets SOC of	0.95
14	H2 Delivered	0	kg	sum of hydrogen delivered to station	
15	H2 Produced	0	kg	sum of hydrogen produced at station	
16	Station Mass Change	-403.9835756	kg	change in mass at station	
17	Duration	23.98333333	hours		
18	StartTime	12:00:00 AM	HH-MM-SS		
19	EndTime	11:59:00 PM	HH-MM-SS		
20	hour 0	2.04326953	kg	amount dispensed this hour	
21	hour 1	1.751373883	kg	amount dispensed this hour	
22	hour 2	2.04326953	kg	amount dispensed this hour	
23	hour 3	4.962226001	kg	amount dispensed this hour	
24	hour 4	9.924452002	kg	amount dispensed this hour	
25	hour 5	16.05426059	kg	amount dispensed this hour	
26	hour 6	19.848904	kg	amount dispensed this hour	
27	hour 7	23.05975612	kg	amount dispensed this hour	
28	hour 8	23.64354742	kg	amount dispensed this hour	
29	hour 9	23.05975612	kg	amount dispensed this hour	
30	hour 10	22.47596483	kg	amount dispensed this hour	

Summary Section

Hourly Amounts

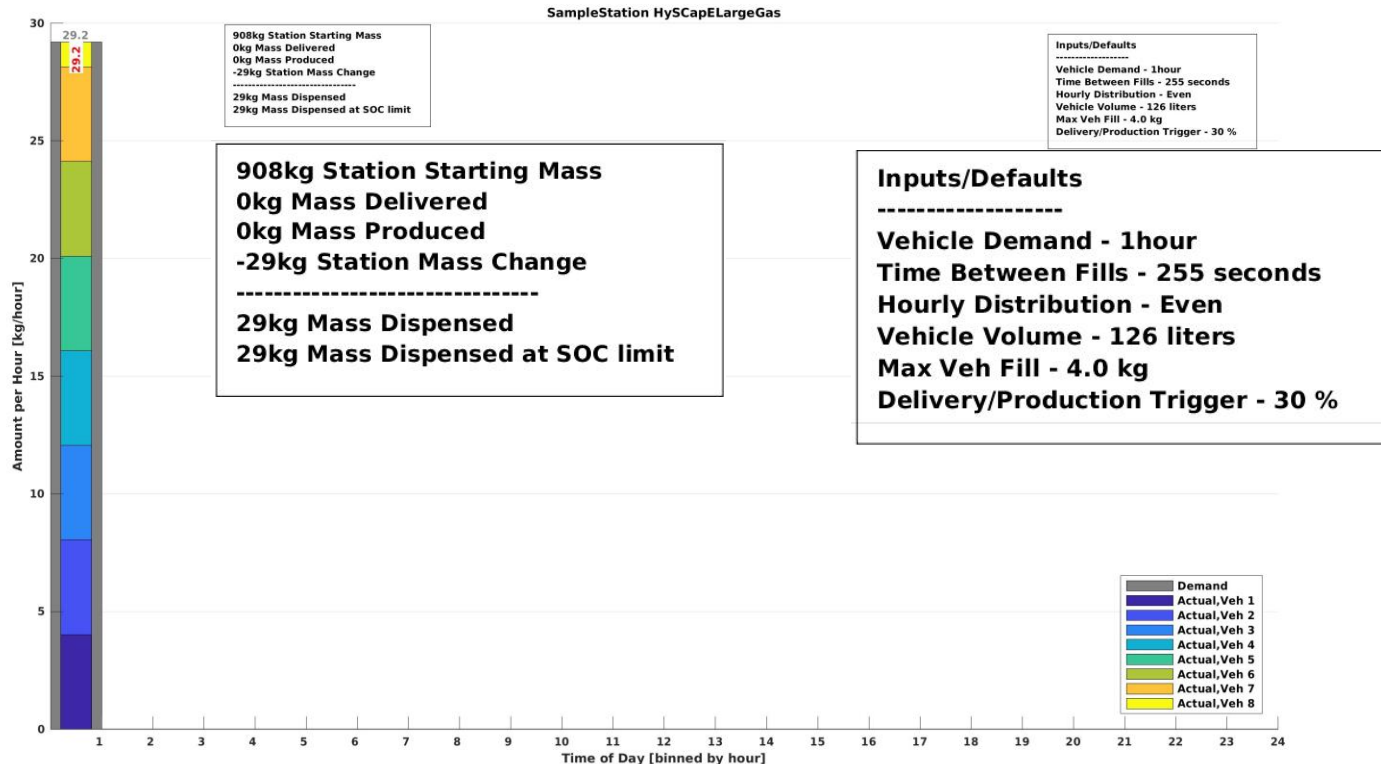
# Large delivered gas Output .xlsx file

	A	B	C	D	E	F	G	H
40	hour 20	11.96772153	kg	amount dispensed this hour				
41	hour 21	8.756869413	kg	amount dispensed this hour				
42	hour 22	5.254121648	kg	amount dispensed this hour				
43	hour 23	3.210852118	kg	amount dispensed this hour				
44	Dispensed by vehicle							
45	Time (start of fill)	Time (end of fill)	Duration	Car Number	Init kg	Final kg	Added kg	Final SOC
46	00:00:01	00:02:05	00:02:04		1 2.957905453	5.001174983	2.04326953	1
47	01:00:00	01:01:45	00:01:45		2 3.249801101	5.001174983	1.751273883	1
48	02:00:01	02:02:07	00:02:06		3 2.957905453	5.001174983	2.04326953	1
49	03:00:00	03:04:05	00:04:05		4 0.982357913	5.001174983	4.01881707	1
50	03:25:53	03:26:50	00:00:57		5 4.057766052	5.001174983	0.943408931	1
51	04:00:00	04:04:05	00:04:05		6 0.982357913	5.001174983	4.01881707	1
52	04:17:15	04:21:20	00:04:05		7 0.982357913	5.001174983	4.01881707	1
53	04:34:30	04:36:23	00:01:53		8 3.114357122	5.001174983	1.886817862	1
54	05:00:01	05:04:07	00:04:06		9 0.982357913	5.001174983	4.01881707	1
55	05:12:57	05:17:03	00:04:06		10 0.982357913	5.001174983	4.01881707	1
56	05:25:53	05:30:00	00:04:07		11 0.982357913	5.001174983	4.01881707	1
57	05:38:49	05:42:54	00:04:05		12 1.003365602	5.001174983	3.997809381	1
58	06:00:00	06:04:07	00:04:07		13 0.982357913	5.001174983	4.01881707	1
59	06:10:21	06:14:28	00:04:07		14 0.982357913	5.001174983	4.01881707	1
60	06:20:42	06:24:48	00:04:06		15 0.982357913	5.001174983	4.01881707	1
61	06:31:03	06:35:10	00:04:07		16 0.982357913	5.001174983	4.01881707	1
62	06:41:24	06:45:15	00:03:51		17 1.22753926	5.001174983	3.773635723	1
63	07:00:00	07:04:06	00:04:06		18 0.982357913	5.001174983	4.01881707	1
64	07:08:38	07:12:45	00:04:07		19 0.982357913	5.001174983	4.01881707	1
65	07:17:15	07:21:21	00:04:06		20 0.982357913	5.001174983	4.01881707	1
66	07:25:53	07:30:00	00:04:07		21 0.982357913	5.001174983	4.01881707	1
67	07:34:30	07:38:37	00:04:07		22 0.982357913	5.001174983	4.01881707	1
68	07:43:07	07:46:10	00:03:03		23 2.035504212	5.001174983	2.965670772	1
69	08:00:01	08:04:08	00:04:07		24 0.982357913	5.001174983	4.01881707	1
70	08:08:38	08:12:45	00:04:07		25 0.982357913	5.001174983	4.01881707	1
71	08:17:15	08:21:22	00:04:07		26 0.982357913	5.001174983	4.01881707	1

Individual Vehicle Fill



# 1 hour back-to-back fueling



# Liquid delivered

## Inputs

Component	Value	Units	Description
Production	0	MPa	output max pressure
Storage	0.33	m3	Volume high pressure (HP) bank %HITRF: 0.342925
Storage	0	m3	Volume medium pressure (MP) bank %HITRF: 1.3224;
Storage	0	m3	Volume low pressure (LP) bank %Default: 2.6108;
Storage	20	m3	Volume of liquid (LQ) bank (22.7125 = 6000 gallons)
Storage	4	#	Number of high prssure banks
Storage	0	#	Number of medium pressure banks
Storage	0	#	Number of low pressure banks
Storage	1	#	Number of liquid banks
Storage	45	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	0	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	0	MPa	Minimum LP bank pressure
Storage	90	MPa	Maximum HP bank pressure
Storage	0	MPa	Maximum MP bank pressure
Storage	0	MPa	Maximum LP bank pressure
Storage	0.92	MPa	Vaporizer output pressure (must be greater than HP compressor minimum) (www.linde-engineering.com.hk/internet.le.le.hkg/zt/images/P_3_4_e_10_150dpi227_5776.pdf?v=.)
Storage	1	logical [0,1]	High pressure bank Eligible for fill, 1=eligible, 0=not eligible
Storage	0	logical [0,1]	Medium pressure bank Eligible for fill, 1=eligible, 0=not eligible

Liquid storage

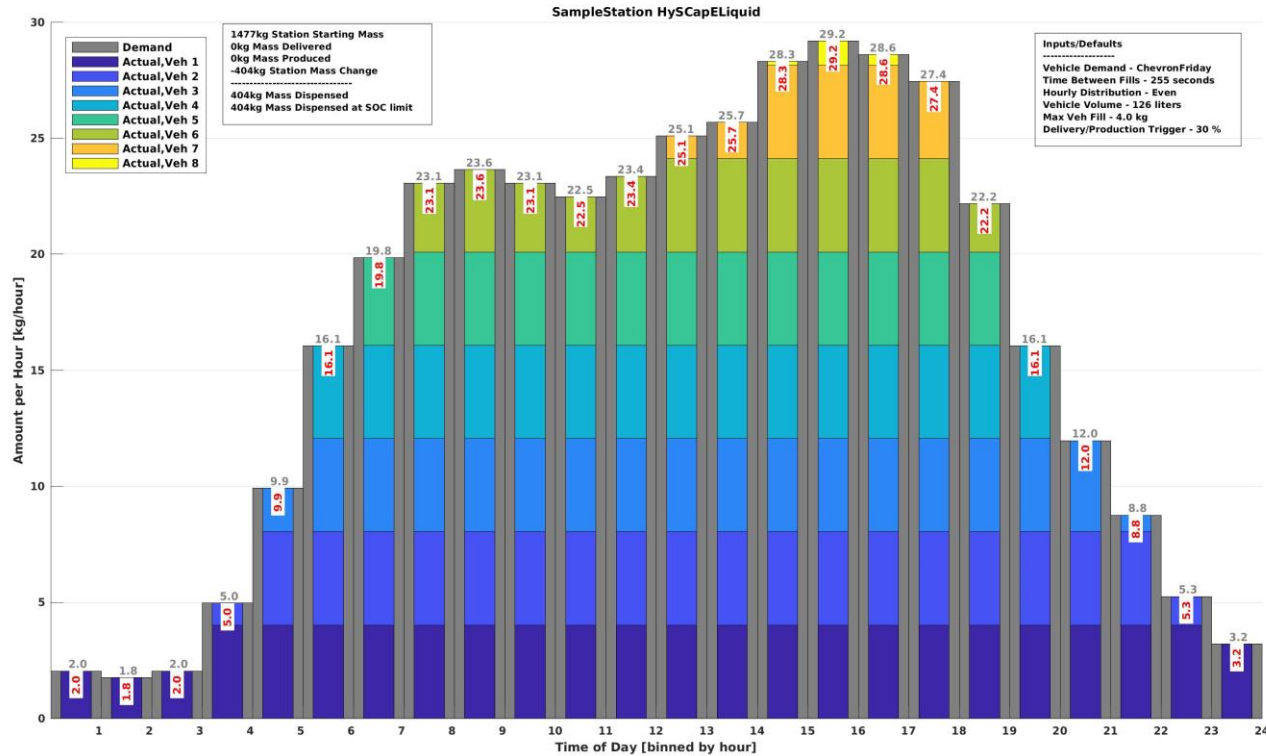
# Liquid delivered

## Inputs

Component	Value	Units	Description
Storage	0	logical [0,1]	Low pressure bank Eligible for fill, 1=eligible, 0=not eligible
Compressor	1	logical [0,1]	Allow compressor to fill bank which are used for dispensing?, 1=yes, 0=no.
Compressor	1	#	Number of high pressure compressors
Compressor	0	#	Number of medium pressure compressors
Compressor	20	MPa	Minimum High pressure compressor (HPc) pressure
Compressor	0	MPa	Minimum Medium pressure compressor (MPc) pressure
Compressor	93	Mpa	Maximum HPc pressure
Compressor	0	Mpa	Maximum MPc pressure
Compressor	25	kg/h	HPc maximum flowrate
Compressor	0	kg/h	MPc maximum flowrate
Compressor	0	kg/h	Liquid pump maximum flowrate
Compressor	100	kg/h	Vaporizer maximum flowrate
Dispenser	20	degC	Ambient temperature
Dispenser	1	#	Maximum number fueling positions capable of simultaneous fill
Delivery	0	kg	Mass per delivery
Delivery	0	#/day	Number of deliveries per day
Delivery	0	#	Number of banks delivering hydrogen
Delivery	0	MPa	Pressure of delivery truck
Delivery	0	kg/s	Delivery flow rate
Delivery	3600	s	Delivery truck dwell time
Delivery	1	selector [1,2]	Fuel delivery type, 1=gaseous, 2=liquid
Liquid	0.4464	kg/s	Liquid truck delivery rate to storage

If using Liquid pump  
Vaporizer flow rate  
must be at least the  
liquid pump flow  
rate

# Liquid delivered *Fill Profile*



# HySCapE 1.0 Assumptions

- Not a design tool. Does not verify equipment.
  - Example: assumes the hydrogen chiller is sized appropriately
  - Example 2: assumes the flow rates specified are achievable
- Average dispensing rate of 1 kg/min
- CSA HGV 4.9 the basis for defining a fill
- Station will not see more demand than the “Chevron gasoline profile”.
- Vehicles are full at 5 kg, with a starting pressure of 10 Mpa
- Ambient temperature used to calculate pressures
- Station storage is 100% at start
- Compression is scaled based on suction pressure
- 2 dispensers double the demand

# Questions and Answers

Question: How is the demand profile used in the model?

Along with the time between fills, it is used to determine how many and when vehicles show up each hour for fueling.

Question: What is HITRF and associated example values in input files?

**H**ydrogen **I**nfrastructure **T**esting and **R**esearch **F**acility at NREL.  
Example values from our station were used in testing and developing the software.

Question: Where can I find more details on how the model works?

- July 20, 2018 workshop [ww2.energy.ca.gov/altfuels/notices/2018-07-20\\_workshop/2018-07-20 ARFVTP Workshop.mp4](https://www.energy.ca.gov/altfuels/notices/2018-07-20_workshop/2018-07-20_ARFVTP_Workshop.mp4)

# Thank you

---

**[www.nrel.gov](http://www.nrel.gov)**

Publication Number

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

