Existing Growth Opportunities for Hydrogen Transportation in California

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March 2006

Feel free to contact me with any comments, questions, and/or any other information you might think useful or interesting to this research effort.

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Introduction

- Many challenges exist to a large-scale transition to a hydrogen fueled transportation system, such as:
  - Status of hydrogen vehicle technologies and
  - Lack of widespread hydrogen production and refueling infrastructure.

Hypothesis

Current industrial hydrogen production infrastructure may offer a launching point for large-scale implementation of hydrogen refueling infrastructure.

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Fuel transition strategies could be based on existing hydrogen markets and production infrastructure.

Case in Point

The high growth rates of the hydrogen industry and of hydrogen demand in refineries offers a unique opportunity for hydrogen transportation in California.

Motivation: Growing Demand, Growing Industries

- In recent years, several large-scale hydrogen production facilities built in US refining centers.
- Industrial hydrogen industry has been growing at 7-10% per year
- Refinery hydrogen is expected to continue growing at, or possibly faster than, its current rate (4%).

Kirschner M., *Chemical Profiles: Hydrogen.* Chemical Market Profiles, 2003.

Motivation: Location, Location

- California's refineries are located amongst its largest transportation demand centers:
  - Los Angeles Basin (LA Basin) and
  - San Francisco Bay Area (SF Bay Area).

Goal

Illustrate the potential of the current hydrogen production infrastructure to fuel light-duty and heavy-duty hydrogen vehicles in California.

Objectives

- Develop the historical context of today's hydrogen industry by
  - Describing the history and evolution of refinery hydrogen demand through discussion of market and policy demand drivers and supply trends; and by
  - Discussing the development of the interdependency of the refining and industrial gas industries.

Objectives

- Discuss important differences between CA's market and the national market.
- Discuss current market conditions and likely future directions

Objectives

- Develop the Hydrogen Production Infrastructure Growth Model to project future hydrogen demand and production capacity in the Los Angeles Basin and the San Francisco Bay Area.
  - Characterize hydrogen demand trends and incorporate these trends into model.
  - Characterize hydrogen production capacity expansion trends and incorporate into model.

Objectives

- Compare various hydrogen vehicle implementation scenarios to the number of hydrogen vehicles that could be fueled from excess hydrogen production capacity.
  - Characterize hydrogen vehicle implementation scenarios for light-duty and heavy-duty vehicles, drawing on existing scenarios used by DOE *and NREL* researchers.
  - Estimate when vehicle demand might affect the rate of capacity expansion.

Objectives

- Compare magnitudes of projected vehicle hydrogen demand growth and projected refinery hydrogen production capacity growth for both the LA Basin and the SF Bay Area
  - Calculate the number of hydrogen vehicles that can be fueled from excess hydrogen production capacity and
  - Estimate when vehicle demand might affect the rate of capacity expansion.

Merchant Hydrogen Data

California Merchant Hydrogen Facilities, compressed gas (Chemical Market Reporter, February 2003)			
Company	**Location**	**Capacity** (MM scfd)	**Capacity for Refineries**
Air Products	Carson	100	66.67
Air Products	Martinez (2 units)	125	83.3
Air Products	Wilmington (2 units)	160	106.67
	Total	**385**	**257**

Refinery Hydrogen Data

Oil and Gas Journal – 2005 Worldwide Refinery Survey
California Refinery Hydrogen [11]

Company	City	Crude Capacity b/cd	Hydrogen Production Capacity (MM scfd)
Big West Oil LLC	Bakersfield	65,000	29.7
Kern Oil Refining	Bakersfield	25,000	0.0
San Joaquin Refining Co. Inc.	Bakersfield	24,300	7.0
Valero Energy Corp.	Benicia	139,500	131.5
BP PLC	Carson	247,000	105.0
ConocoPhillips	Carson and Wilmington	260,000	100.8
Chevron Corp.	El Segundo	161,000	139.0
Tesoro Corp.	Golden Eagle (Martinez)	52,000	105.0
Paramount Petroleum Corp.	Long Beach	138,700	0.0
Shell Oil Products US	Martinez	157,600	101.3
Chevron Corp.	Richmond	225,000	155.0
ConocoPhillips	Rodeo and Santa Maria	120,000	88.9
ExxonMobil Refining Supply Co.	Torrance	149,500	159.0
Valero Energy Corp.	Wilmington	80,000	50.0
Shell Oil Products US	Wilmington	100,000	110.0
	Total	1,944,600	1,282.2

Initial Findings: Vehicles fueled

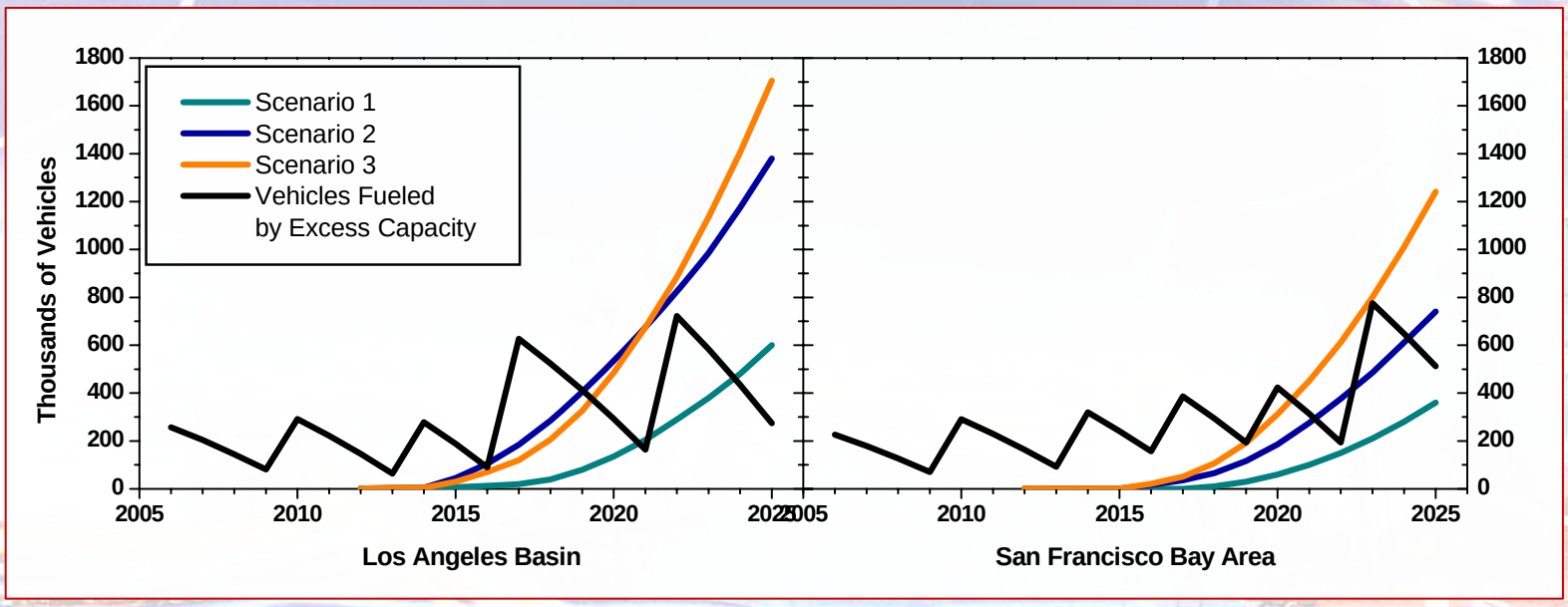
- Based on the assumptions I've made, almost 5% of total production capacity could be reliably available as fuel for hydrogen vehicles, and

- Using 1% of each region's 2006 total refinery hydrogen production capacity
  - 19,000 hydrogen light-duty fuel-cell vehicles could be fueled in the LA Basin (6.64 MMscfd H2) and
  - 17,000 could be fueled in the SF Bay Area (5.82 MMscfd).

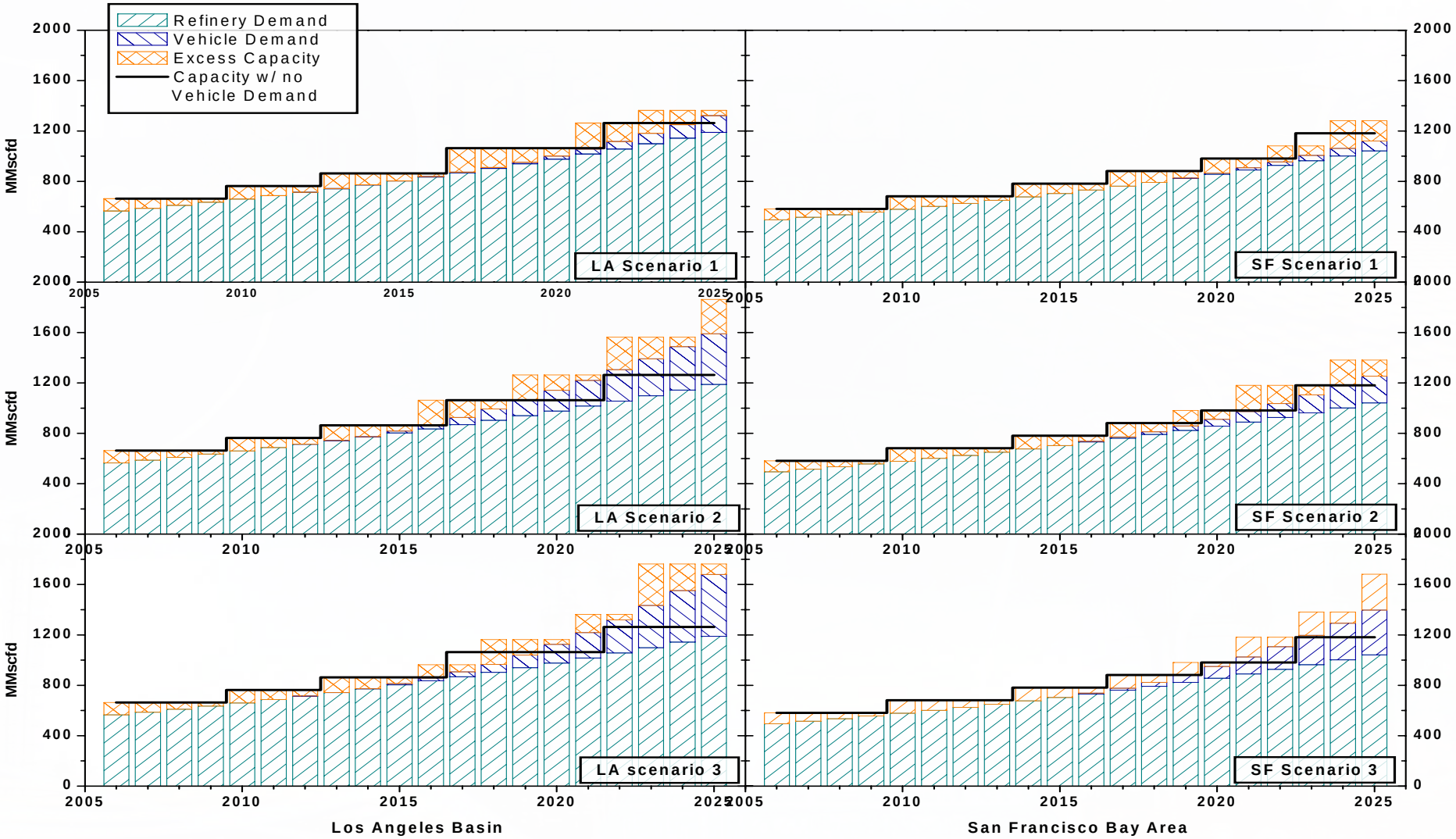
Refinery Hydrogen data source:
2005 Worldwide Refining Survey, in *Oil & Gas Journal*, J. Stell, Editor. 2005, PennWell Publishing Company.

Initial Findings: Market Effects

- An emerging hydrogen vehicle market could begin affecting the rate of refinery hydrogen production capacity when the total number of vehicles is between 200,000 (~64 MMscfd H2) and 300,000 (~82 MMscfd H2).
- According to scenarios developed by the DOE Hydrogen Program, this could happen as soon as
  - 2018 in the LA Basin and
  - 2020 in the SF Bay Area.

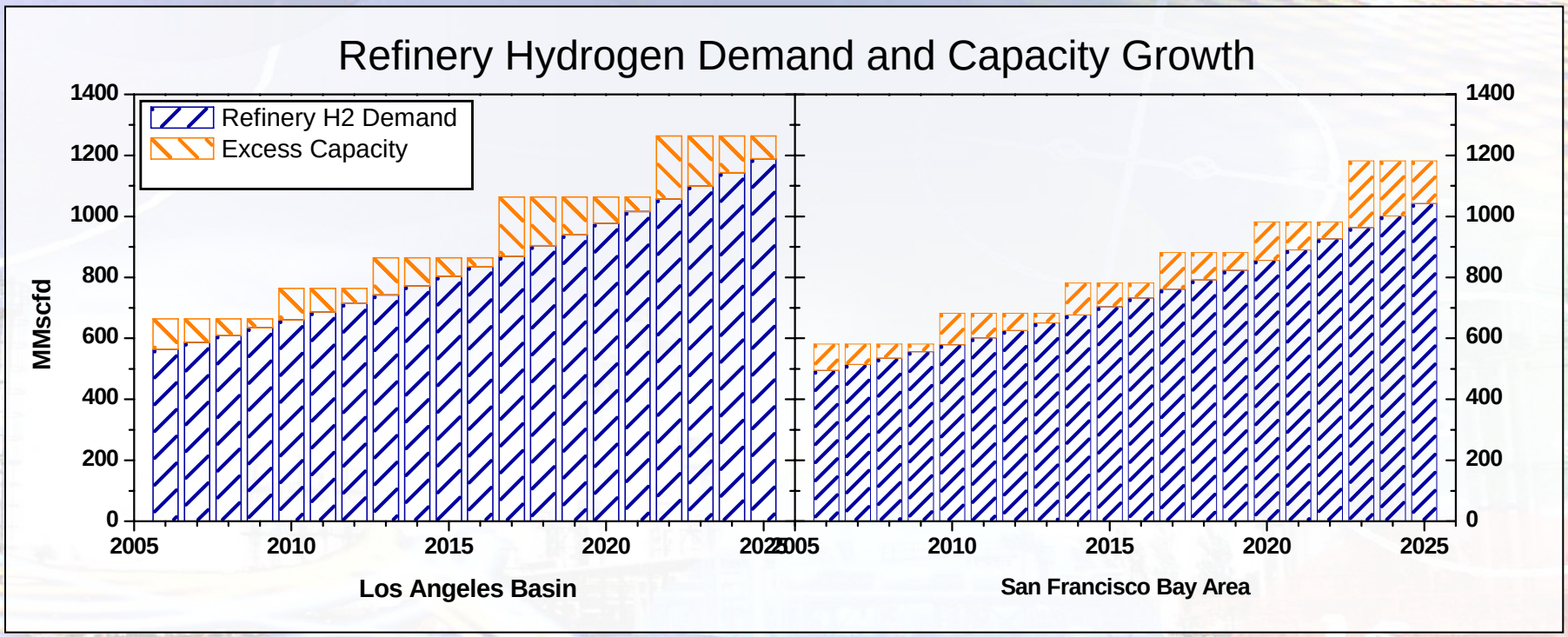


Potential growth in hydrogen demand for both refining and vehicle fuel and the capacity growth needed to meet combined demand.



Method: Refinery Hydrogen (RH2) Demand and Capacity Expansion

- Production Capacity from OGJ 2006 Worldwide Refinery Survey
  - Los Angeles Basin and San Francisco Bay Area



Key Assumptions Needing Clarification

- Current refinery hydrogen production facilities are operating at 85% of total production capacity.
- Current total refinery hydrogen demand is equal to 85% of total production capacity.
- Total refinery hydrogen demand grows 4% per year.
- Additional capacity in increments of 100 MMscfd is added when an area's total refinery demand is equal to 95% of total capacity.
- Additional capacity is built as a new central production plant serving all refineries for a given area.
- Hydrogen purity is already sufficient for use in fuel cells.

Outline of Data Needs

- For each area, what is the total installed hydrogen production capacity and total hydrogen demand, including refinery and other production facilities?
- How many facilities are in each area and for each what is the production capacity, the hydrogen demand, and the location?
- How is hydrogen demand growing and how can future growth be best characterized?
- How can capacity expansion and growth be best characterized?
- How much excess capacity might be reliably available for hydrogen vehicles?
- What is the average purity of produced hydrogen?

Outline of Data Needs

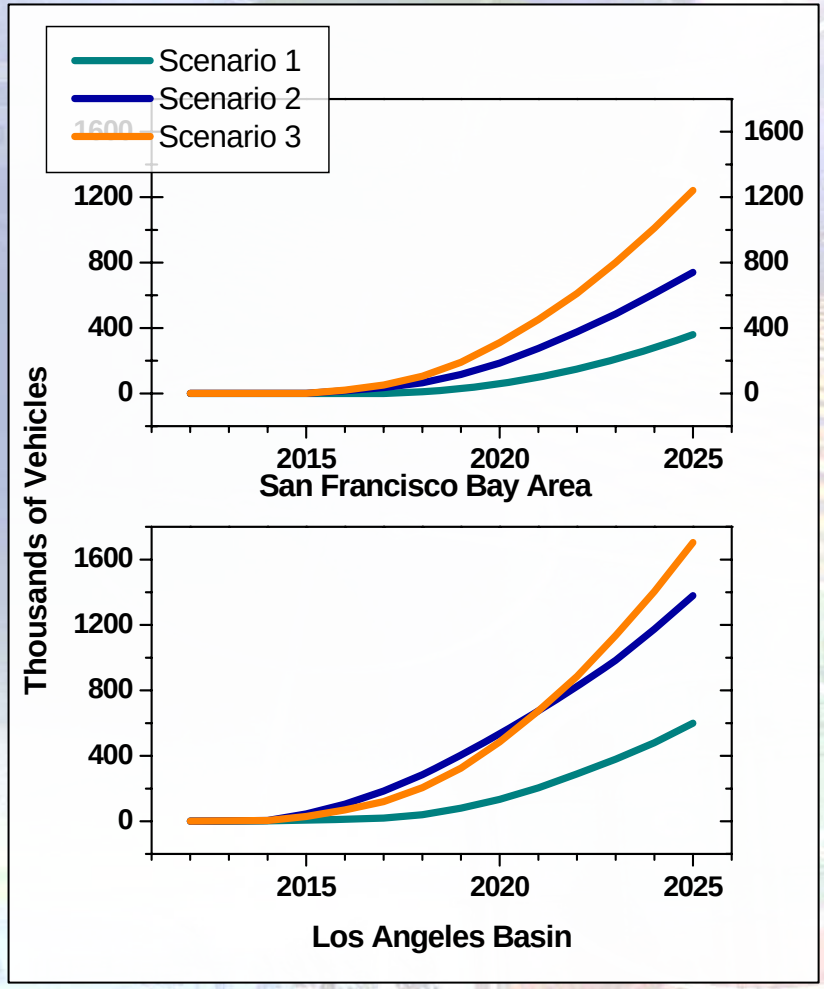
- For each area, what is the total installed hydrogen production capacity and total hydrogen demand, including refinery and other production facilities?
- How many facilities are in each area and for each what is the production capacity, the hydrogen demand, and the location?
- For each refinery, what is the total installed hydrogen production capacity and total hydrogen demand?
- Do refinery hydrogen production facilities serve customers other than the refinery where the facility is located? If so, how can this be best incorporated into this analysis?
- How is hydrogen demand growing and how can future growth be best characterized?
- How can capacity expansion and growth be best characterized?
- How much excess capacity might be reliably available for hydrogen vehicles?
- What is the average purity of produced hydrogen?

Method: Vehicle Hydrogen Demand

- US DOE Hydrogen Program 2010-2025 Scenario Analysis
- Projects introduction of vehicles to market for major US metropolitan areas.

- Scenario 1:
  - Vehicle introduced to market in 2015.
  - 2 million vehicles nationwide by 2025.
- Scenario 2:
  - Vehicle introduced to market in 2012.
  - 5 million vehicles nationwide by 2025.
- Scenario 3:
  - Vehicle introduced to market in 2012.
  - 10 million vehicles nationwide by 2025.

- Gradual increase in vehicle efficiency
- 12,000 miles per year



Next Steps

- Develop systematic method for capacity expansion based on
  - Capacity Characteristics
  - Capacity Expansion
  - Aggregate vs. Disaggregate Demand
  - Facility Timeframe
  - Available vs. Actual Excess Capacity
  - Other Demand Sectors
- Explore transition strategies based on developed capacity expansion method.

Transition Strategies

- Explore transition strategies
  - Gov’t support
  - Reserved capacity for vehicles
  - Vehicle fleets
  - Non-LDV fleets

Capacity Characteristics

- What is an ideal capacity factor?
- When new facilities are built, what is a typical initial capacity factor?
- Is there a maximum or critical capacity factor at which point it would be necessary to build a new facility? If so, what is it?

Capacity Expansion

- How is existing capacity likely to be expanded?
- How is new capacity likely to be built?
- Will it likely expand to meet aggregate demand or disaggregate?
- Will new facilities likely be single or multi purpose? Onsite or offsite?
  - In some cases large-scale production facilities have been built onsite at specific refineries but also serve other refineries and other customers, and sometimes a new facility is built offsite of a specific customer and serves multiple customers.
- How can I characterize capacity expansion in my calculations of capacity growth and available excess capacity so that I capture all capacity and so that I don’t double count any?

Facility Timeframes

- When a new facility is built, what is a typical timeframe for which the facility is expected to meet demand?
- What is the average lifetime of a facility?
- What is the average age of existing facilities?

Available vs. Actual Excess Capacity

- Available capacity at any given facility is most likely much less than the actual operating excess capacity.
  - For example, refinery hydrogen demand has seasonal variation. Therefore, at times the actual refinery demand is less then the supply they have contracted for.
  - Also, portions of excess capacity are reserved for specific customers in order to fulfill specific contractual guarantees-of-supply.

- What are typical amounts of reserve capacity that I could factor in when projecting future capacity growth?
- How much capacity might be reliably available for hydrogen vehicles?

Other Demand Sectors

- While the calculations shown in this presentation are based on aggregate refinery hydrogen production capacity, I would also like to account for non-refinery hydrogen production facilities.

- However, the last several years in the US have seen most large-scale hydrogen production facilities being built for specific refineries or for a group of refineries, thus the initial focus of this research on refinery hydrogen demand.

- In California, what are the other, non-refinery uses of hydrogen?
- What are the respective shares of demand?
- What are current and projected demands in each of these sectors?
- How is demand likely to evolve?

Specific Facility Information

- How many facilities are in each region?
- Where is each facilities located?
- The actual facility locations would help determine how a vehicle refueling infrastructure might be built up if these facilities produced some hydrogen for vehicles.
- What kind of, if any, connecting hydrogen delivery infrastructure exists between these facilities? i.e. pipeline vs. truck delivery.
- When was each facility built?
- With what timeframe was each facility built?
- What are the capacity characteristics of each facility (e.g. total capacity, capacity factor, excess capacity, reserve capacity, idle capacity)?
- For which purpose(s) is the hydrogen being used and what share of capacity does each account for?
- What is the average hydrogen purity at these facilities?
- What is the temporal demand/production distribution of each facility?

Thank you very much for your time.

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