(Hydrogen) Service Stations 101

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DISCLAIMER

Opinions expressed within are strictly those of the presenter and do not necessarily represent ConocoPhillips Company.
Presentation Outline

• *Introduction to ConocoPhillips*
• Introduction to Service Stations
• Comparison of Conventional with Hydrogen Fueling Stations
• Hydrogen Fueling Life Cycle
• Practical Design Example
• Concluding Observations
ConocoPhillips

- 7th on Fortune’s list of largest companies (2003 revenues)
- 3rd largest integrated petroleum company in U.S.
- 1st (largest) petroleum refiner in U.S.
- 14,000 retail outlets (350 company-owned) in 44 states
  - Brands: Conoco, Phillips 66, 76
- 32,800 miles pipeline, owned or interest in
- 64 terminals: crude, LPG, refined products
- Power generation
  - Own interest in several plants, U.K. and U.S. (about 1500 MW net)
  - Focused on integrated solutions with Upstream and Downstream
- Involvement with DOE hydrogen program
  - Energy partner in FreedomCAR and Fuel Partnership
  - Member of California Hydrogen Infrastructure Project Team that includes Air Products, Toyota, Honda, Nissan, BMW and others
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Service station evolution from selling gasoline to marketing a variety of products
## Service Station Product-Mix Timeline

<table>
<thead>
<tr>
<th>Year</th>
<th>Gasoline</th>
<th>Lube. Oil</th>
<th>Crude Oil Products</th>
<th>Vehicle Maintenance &amp; Repair</th>
<th>Convenience Stores</th>
<th>Hyper-markets</th>
</tr>
</thead>
<tbody>
<tr>
<td>1920</td>
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<td>1930</td>
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<td>1940</td>
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<td>1950</td>
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<td>1960</td>
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<tr>
<td>1970</td>
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<tr>
<td>1980</td>
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<tr>
<td>1990</td>
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<tr>
<td>2000</td>
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</tbody>
</table>

Today’s service stations are more about soda than service.
Station Characteristics -- Customer

- Product quality *
- Product availability *
- Competitively priced *
- Simple to dispense *
- Reliable dispensing *
- Fast dispensing *
- Convenient location
- Easy access to / from
  - Property
  - Pumps
  - C-store

- Quick turnaround
- Desirable C-store product line
- Aesthetically pleasing
- Clean facilities
- Safe

* Referring to motor fuel
Station Characteristics -- Owner

- Safe
- Compliant with codes and regulations
- Reliable and timely delivery of product to the station
- Competitive price from supplier
- Loyalty program
- Minimal labor
  - Attention
  - Expertise
- Minimal downtime
- Minimal maintenance
- Fast customer turnaround
  - Fast dispensing
  - Easy access
- Good (high traffic) location
- Minimal investment
  - Small capital costs
  - Small footprint
- Good access for supply / maintenance vehicles
  - Away from customer traffic
  - Fast stocking
  - Easy supply and maintenance access
- Strong ancillary business (to supplement skinny fuel margins)
Station Characteristics -- Community

- Safe
- Compliant with codes and regulations
- Quiet
- Acceptable emissions
- Clean and neat
- Aesthetically pleasing
- Small footprint

Innocuous and inconspicuous
Absent any profound motivation to adopt hydrogen (such as a serious disruption of petroleum distribution), anticipate that

– customers, owners and communities will be critical, even skeptical, of hydrogen fueling stations

– they will expect hydrogen fueling stations to provide at least the same degree of safety and quality of product, performance and experience that conventional service stations provide
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• Introduction to ConocoPhillips
• Introduction to Service Stations
• **Comparison of Conventional with Hydrogen Fueling Stations**
• Hydrogen Fueling Stations Life Cycle
• Practical Design Example
• Concluding Observations
GASOLINE PRODUCT COST

April, 2004: $1.80 / gallon
($1.39 / gallon before taxes)

Source: EIA (April, 2004)
### Distribution & Marketing Cost Component – U.S. Gulf Coast

<table>
<thead>
<tr>
<th>Transport Segment</th>
<th>Cost ($ / Gallon)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refinery to pipeline</td>
<td>0.002 - 0.006</td>
</tr>
<tr>
<td>Pipeline tariff</td>
<td>0.007 (80 mi) - 0.032 (1610mi)</td>
</tr>
<tr>
<td>Terminal service</td>
<td>0.004 - 0.006</td>
</tr>
<tr>
<td>Truck loading</td>
<td>0.006 – 0.008</td>
</tr>
<tr>
<td>Trucking</td>
<td>0.015 – 0.020</td>
</tr>
<tr>
<td>Retail margin *</td>
<td>0.05 – 0.20</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.084 – 0.272</strong></td>
</tr>
</tbody>
</table>

*Includes operations, maintenance, insurance, profit, etc.

SOURCE: DOE FreedomCAR and Fuels Initiative Delivery Tech Team
ON-SITE, ELECTROLYTIC HYDROGEN COST

Target Electrolytic Hydrogen Price Breakout

* “Other” includes power conversion, compression, storage and dispensing, balance of plant, O&M, labor, profit, etc.

2010 Target: $3.31 / kg
($2.85 / kg before taxes)

Taxes
Cell Stack
Other *
Electricity

Source: Up-dated DOE MultiYear RD&D Plan
## Components of “Other” Cost

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>Cost ($/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power conversion</td>
<td>0.09</td>
</tr>
<tr>
<td>Balance of plant (H2 purification, water removal)</td>
<td>0.08</td>
</tr>
<tr>
<td>Compression</td>
<td>0.18</td>
</tr>
<tr>
<td>Storage and dispensing</td>
<td>0.06</td>
</tr>
<tr>
<td>Other (O&amp;M, labor, plant construction, profit, etc.)</td>
<td>0.32</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.73</strong></td>
</tr>
</tbody>
</table>

Source: Updated DOE MultiYear RD&D Plan
Equipment Comparison

Conventional
- Product storage tanks
  - Inexpensive, “low tech”
  - 8/10/12/15/20,000 gallon
  - Diesel, premium, regular
- Pumps, leak detection
- Mixers (octane)
- Vapor collection
- Dispensers
- Pad, guards, canopy
- C-Store (3,000 sq.ft.)
- Car wash

Hydrogen
- Product storage tanks
  - Expensive, “high tech”
  - Single product
- Feed preparation
- Electrolyzer
- Compressor
- Product treatment
- Tube trailer drop
- Dispensers
- Pad, guards, canopy
- C-Store
- Car wash
Service Station Differences

Conventional
- “Distribution” problem
- Retailer purchases finished product priced competitively in free-market
- National codes
- Product differentiation
  - Multiple grades
  - Additives
- Economic justification
- Many customers / competitors

Hydrogen
- “Production” problem
- Retailer purchases electricity or natural gas in regulated system
- Local codes
- Limited opportunity for product differentiation
  - Renewable, non-renewable
- Non-economic basis (security, environment)
- Few customers / competitors
# Service Station Differences (cont)

<table>
<thead>
<tr>
<th>Conventional</th>
<th>Hydrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Standard risk</td>
<td>• Added risk</td>
</tr>
<tr>
<td>• Marketing</td>
<td>• Production activity *</td>
</tr>
<tr>
<td>• Competition</td>
<td>• Station technology *</td>
</tr>
<tr>
<td>• Modest investment</td>
<td>• Vehicle technology</td>
</tr>
<tr>
<td>• Insurability</td>
<td>• Larger investment</td>
</tr>
<tr>
<td>• History</td>
<td>• Insurability</td>
</tr>
<tr>
<td>• Nature of fuel</td>
<td>• Lack of history</td>
</tr>
<tr>
<td>• Liquid hydrocarbon</td>
<td>• Nature of fuel</td>
</tr>
<tr>
<td>• Liability</td>
<td>• Hydrogen</td>
</tr>
<tr>
<td>• Bad fuel – shared</td>
<td>• Liability</td>
</tr>
</tbody>
</table>

* On-site production represents a significant redistribution of production risk from central plants to stations involving new technologies.
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• *Hydrogen Fueling Life Cycle*
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NRC Projected Hydrogen Fueling Life Cycle

• Initial period
  • Demonstration stations
  • Central production, trucked to stations

• Transition period
  • Distributed on-site production
  • Primarily natural gas reforming and grid-based electrolysis
    • Small (5%) load increase on infrastructure
  • Some renewable production (wind, solar)

• Long term
  • Unknown
Initial and Early Transition Periods
“Hydrogen Highways”

- California
  - 150 – 200 stations, $75 – 200 million
  - Every 20 miles along major highways
  - Higher concentrations in larger towns
  - Operational in 2010

- British Columbia
  - Between Vancouver and Whistler (about 80 miles)
  - Operational by 2010 Olympics in Whistler

- Illinois
  - I-90 from Indiana to Wisconsin

- New York State Thruway
Early Life Cycle Issues with Hydrogen Refueling Stations

- How to price product (especially at remote stations)?
  - How to ensure adequate returns to induce investment?
  - Will Public Utilities Commission regulate?
- How to ensure (esp. remote) stations have adequate fuel?
- How will system evolve?
  - Will neighborhood stations share production?
- How to address hydrogen codes that tend to be local?
- How to acquire benefits of high volume manufacture?
  - How to limit the number of standard sizes?
  - Will the number of stations support high manufacturing volumes?
  - Will the number of stations be adequate to support competition among multiple manufacturers?
- How to educate populace?
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Hydrogen Station Design Considerations

- Avoid running out of product
  - Design  • Truck delivery  • Price  • Rationing
- Optimize cost across capital and operations
  - Capital equipment
    - Production equipment  • Product storage
  - Individual equipment design
    - Turndown  • Efficient cycling
    - Durability to cycling
- Variable utility or feed availability and cost
  - Continuous (grid)  • Intermittent (wind, solar)
  - Peak / off-peak electric rates
- Site
  - Location  • Layout  • Footprint

25
May – July Daily Demand (Sales Volume) Data for a Neighborhood Service Station

Demand and rates expressed as multiples of the average demand and rate over the time period.
Tank Capacity Required to Keep Tank from Emptying – Constant Production Rate

Hours of Production Inventory While Producing at the Average Rate

Maximum volume = Tank volume required to avoid an empty tank

Initial inventory to avoid an empty tank
Production Equipment Sizing to Reduce Tank Requirement – 20% Production Overcapacity

Maximum = Required tank capacity

Inventory and Production as Multiple of Average Rate

- Storage
- Production

Days

Inventory (Hours @ Average Rate)

Flow Rate (Multiple of Average Flow)
Equipment Sizing – 40% Overcapacity With Small Off-Peak Incentive

Inventory and Production as Multiple of Average Rate

- Storage
- Production

Days

Inventory (Hours @ Average Rate)

Flow Rate (Multiple of Average Flow)

Daily production reductions made during times at peak electric rate
Equipment Sizing – 60% Overcapacity
With Larger Off-Peak Incentive

Maximum = Required tank capacity

Near-daily shutdowns to avoid peak electric rate periods

Inventory and Production as Multiple of Average Rate

Flow Rate (Multiple of Average Flow)

Days

Inventory (Hours @ Average Rate)
Design Trade-offs

- Storage capacity *
  - storage technology currently under debate
  - 5,000 psi • 10,000 psi • liquid • packed
- Hydrogen production capacity *
  - immediate needs • future demand
- Peak / off-peak operation ***
- Desired hydrogen inventory level **

* Fixed capital ** Working capital *** Operating cost
### Effect of Production Equipment Overdesign on Target Hydrogen Cost, Ignoring Tank Savings

<table>
<thead>
<tr>
<th></th>
<th>Reformer</th>
<th>Electrolyzer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capacity</strong></td>
<td>1.0</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Scaling Factor</strong></td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Fixed Cost</strong></td>
<td>0.5</td>
<td>0.582</td>
</tr>
<tr>
<td><strong>Non-FC</strong></td>
<td>0.5</td>
<td>0.418</td>
</tr>
<tr>
<td>**H2 Cost ***</td>
<td>$1.500</td>
<td>$1.256</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>1.0</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Scaling Factor</strong></td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>Fixed Cost</strong></td>
<td>0.3</td>
<td>0.373</td>
</tr>
<tr>
<td><strong>Non-FC</strong></td>
<td>0.7</td>
<td>0.627</td>
</tr>
<tr>
<td>**H2 Cost ***</td>
<td>$2.850</td>
<td>$2.552</td>
</tr>
</tbody>
</table>

*Steady state production cost
Concluding Observations

• Current U.S. motor fuel production, marketing & distribution
  • Optimized -- evolved over decades and is continuing to evolve
  • Despite stability, system subject to disruptions
• Distributed (on-site) motor fuel production is a new paradigm
  • How much of old paradigm is applicable?
  • What will we fail to anticipate?
• Hydrogen production cost expected to exceed that of conventional motor fuels for extended period of time
• Reallocation of production risk premium to fueling stations
  • Production shifts to stations
  • New (riskier) production technologies are employed
• Success of the “hydrogen economy” depends upon reliable availability of fuel, especially in remote areas, which will create a requirement for dependable backup of hydrogen stations that use renewable power sources
Concluding Observations (cont.)

• Development continues on other vehicular technologies
  • hybrid autos
  • battery-powered autos
  • advanced gasoline or diesel engines

• Effects of exogenous factors
  • Middle East oil disruption
  • many oil producers have the ability to substantially cut oil price

• Public and consumer response
Take Away

• Hydrogen must integrate into a system where fuel currently is important, but not preeminent
• On-site production entails a significant redistribution of risk
• Design of on-site production facilities will be complex and significantly impact station profitability
• Barring exceptional circumstances, petroleum-based fuels will have a cost advantage for an extended period of time
Thank you

Questions?
ON-SITE, NG REFORMER HYDROGEN COST

2010 Target: $1.91 / kg
($1.50 / kg before taxes)

Target NG Reformer Hydrogen Price Breakout

* “Other” ($0.30/kg) includes O&M, rent, utilities, site preparation, etc. – excludes operator profit

Source: DOE MultiYear RD&D Plan
## Components of “Processing” Cost

<table>
<thead>
<tr>
<th>Cost Component</th>
<th>Cost ($/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reforming (excluding natural gas)</td>
<td>0.24</td>
</tr>
<tr>
<td>Purification</td>
<td>0.03</td>
</tr>
<tr>
<td>Compression</td>
<td>0.24</td>
</tr>
<tr>
<td>Storage and dispensing</td>
<td>0.11</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.62</strong></td>
</tr>
</tbody>
</table>

Source: DOE MultiYear RD&D Plan
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- Dispensers
- Pad, guards, canopy
- C-Store and car wash