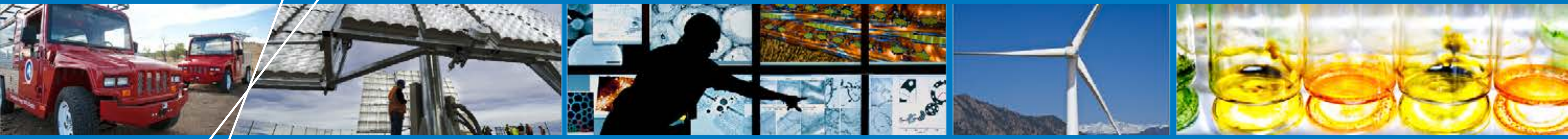
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Hawaii Hydrogen Initiative (H2I) Financial Scenario Analysis



Michael Penev, Marc Melaina, Aaron Brooker

2013 DOE Hydrogen and Fuel Cells Program Review

National Renewable Energy Laboratory

May 14, 2013

Project ID AN042

Overview

Timeline

Project start date: Q1, FY12
Project end date: Q1, FY13
Percent complete: 100%

Barriers

4.5.A: Future Market Behavior
4.5.B: Stove-piped/Siloed Analytical Capability
4.5.D: Insufficient Suite of Models and Tools
4.5.E: Unplanned Studies and Analysis

Budget

Total project funding: $230k
100% DOE-funded
FY2012: $200k
FY2013: $30k

Partners

Louis Berger Group	[H2I - lead]
General Motors	[FCEV deployment lead]
U.C. Irvine	[station placement analysis]
Hawaii Gas	[gas producer & supplier]
Wellford Energy	[financial modeling guidance]

Project Overview

Approach

Effects of Technology Cost Parameters on Hydrogen Pathway Succession

H2I Analysis Team:
General Motors
University of Irvine
Hawaii Gas

H2I, NREL, FCT Office, CaFCP, EIN & External Reviews

Analysis Framework

H2A design parameters
AEO gasoline prices
HSCC* fueling station costs
IEA global FCEV adoption
NRC cost of FCEVs

Models & Tools

SERA Financial
ADOPT sales model

Studies & Analysis

H2I Financial Scenario Analysis:
Station clusters & rollout, finances and incentive analysis

Outputs & Deliverables

Scenario analysis for H2I

Report of findings

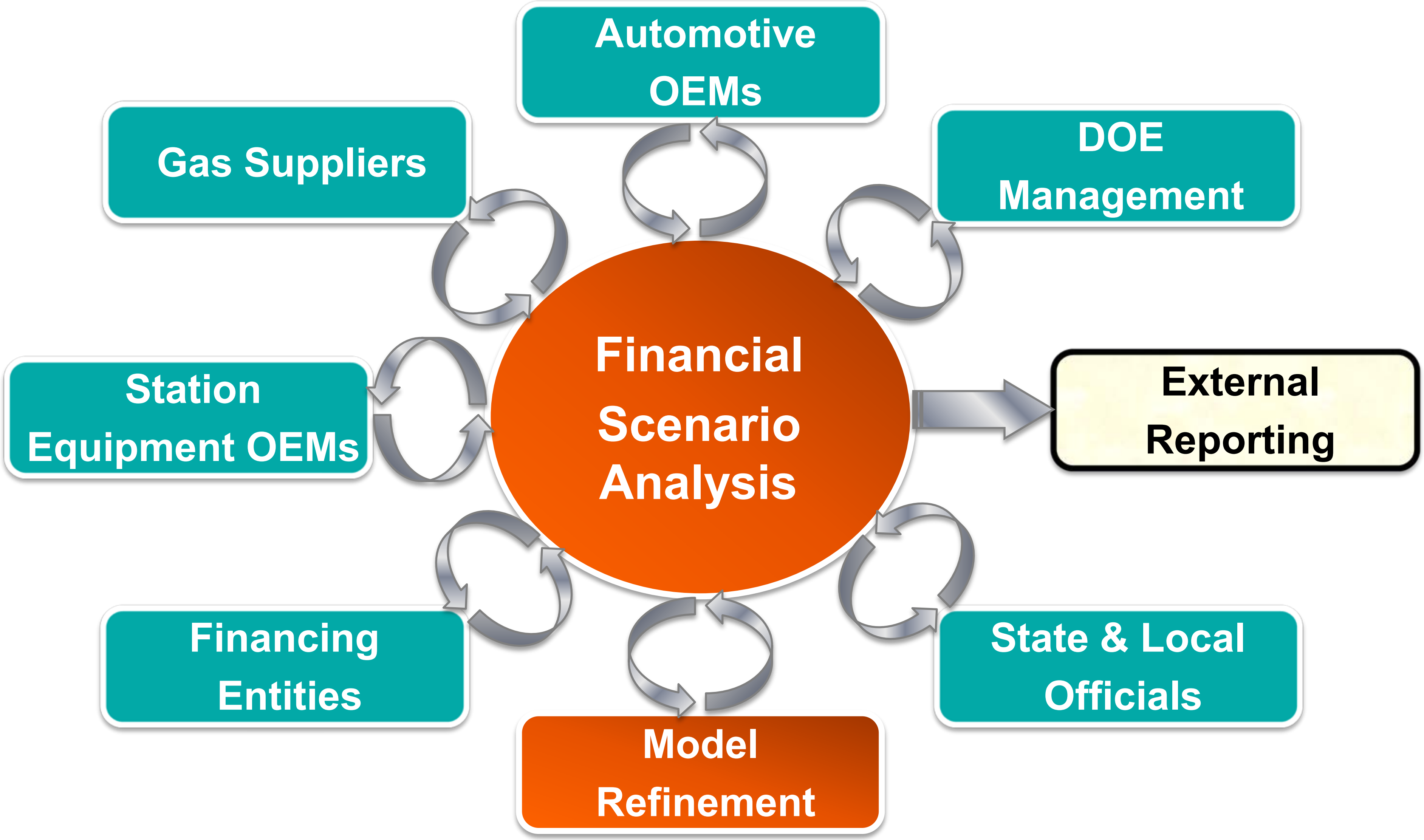
Improved understanding of market adoption, infrastructure phases, and incentive requirements for FCEV and station deployment.

National Labs
None

***HSCC = Hydrogen Station Cost Calculator, NREL Publication Pending**

Relevance: Financial Tool for Stakeholders

Analysis incorporates interests of many stakeholders for station cluster financial analysis



Relevance: Objectives

Analysis helps to identify opportunities and constraints for equity, debt, and public financing

Produce financial projection scenarios

- Consider vehicle adoption rates
- Determine infrastructure support requirements
- Evaluate full range of expenses
- Apply competitive revenue ceiling
- Perform accounting cycle analysis
- Perform multi-year financing projections

Provide Hawaii Hydrogen Initiative (H2I) team with scenario analysis

- Communicate risk and sensitivities
- Facilitate strategic planning
- Evaluate incentive requirements

Approach: Model Structure

Overall model strategy evaluates station supply chain with vehicle sales as an input.

Vehicle Sales

- Promotional introduction
- Private vehicle adoption
- Market competition
- Fleet vehicles
- Fuel efficiency
- Driving habits

Fueling Stations

- Station coverage
- Station size distribution
- Station types

Production & Delivery

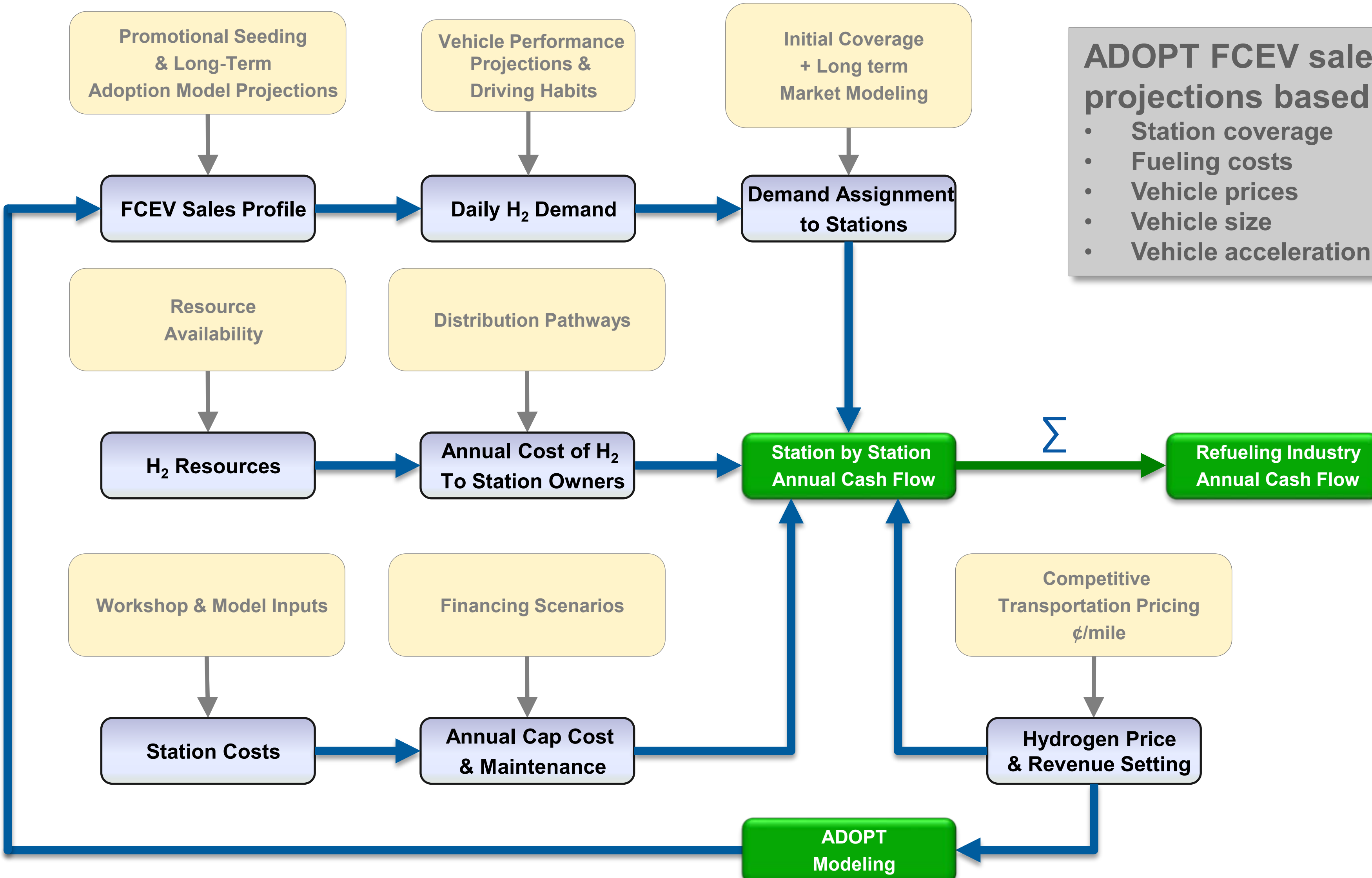
- Production sources
- Delivery methods
- Supply chain costing

Financing & Incentives

- Multi-source financing
- Incentive requirements
- Risk analysis

Approach: Model Structure

Model is integrated with vehicle choice modeling
Automotive Deployment Options Projection Tool (ADOPT model)

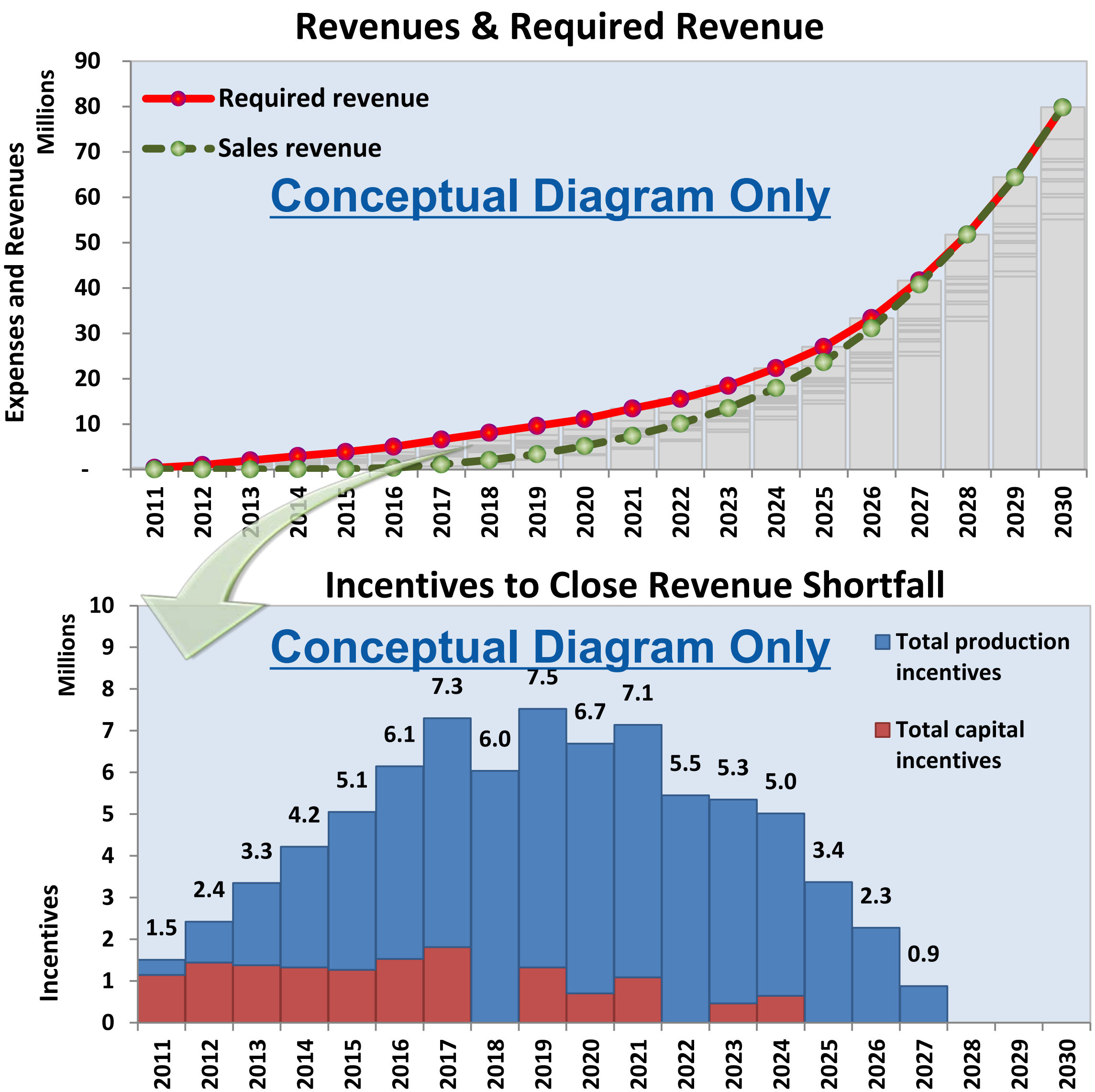


ADOPT FCEV sales projections based on:

- Station coverage
- Fueling costs
- Vehicle prices
- Vehicle size
- Vehicle acceleration

Approach: Model Structure

Model structure quantifies how the revenue shortfall can be filled with multiple types of incentives.



Incentives were split in two components:

Production incentive

- Incentivizes good station placement & efficient operation
- Closes operating expense revenue gap

Capital incentive

- Reduces up-front cost barrier to market entry
- 50% reduction in capital expenses, tapering out by 10% annually after 2020.
- Applies on first time installations and upgrades

Accomplishments: Scenario Analysis Provided

**Multiple scenarios were produced internally –
Two are articulated in this presentation**

Baseline scenario (low vehicle sales)

- **Modest vehicle incentives (US & HI)**

Optimistic scenario (high vehicle sales)

- **Full parity vehicle incentives**
- **Lower cost fuel**

Global inputs for both scenarios

- **Global hydrogen infrastructure source:**
  "Transport, Energy and CO2", IEA 2009
  http://www.iea.org/textbase/nppdf/free/2009/transport2009.pdf
- **Station cost vs. cumulative infrastructure:**
  NREL Hydrogen Station Cost Calculator (HSCC) 2012
- **Vehicle cost vs. global deployment:**
  "Transitions to alternative transportation technologies – a focus on hydrogen", NRC, 2008 (temporal increase in market share Case 1 was used for all analysis)

Accomplishments: Scenario Analysis Provided

Key vehicle parameters were selected for ADOPT analysis

Fuel cell vehicle efficiency

- Both scenarios use the following on-road, fleet average fuel efficiencies
  - 68 mpg in 2015
  - 72 mpg in 2050

Acceleration

- 6.5 seconds for both scenarios (0-60 mph)
- This may be somewhat optimistic, rationale is superior 0-40 mph electric drive acceleration, and largely urban driving conditions on Oahu.

Range

- 300 miles per full refueling

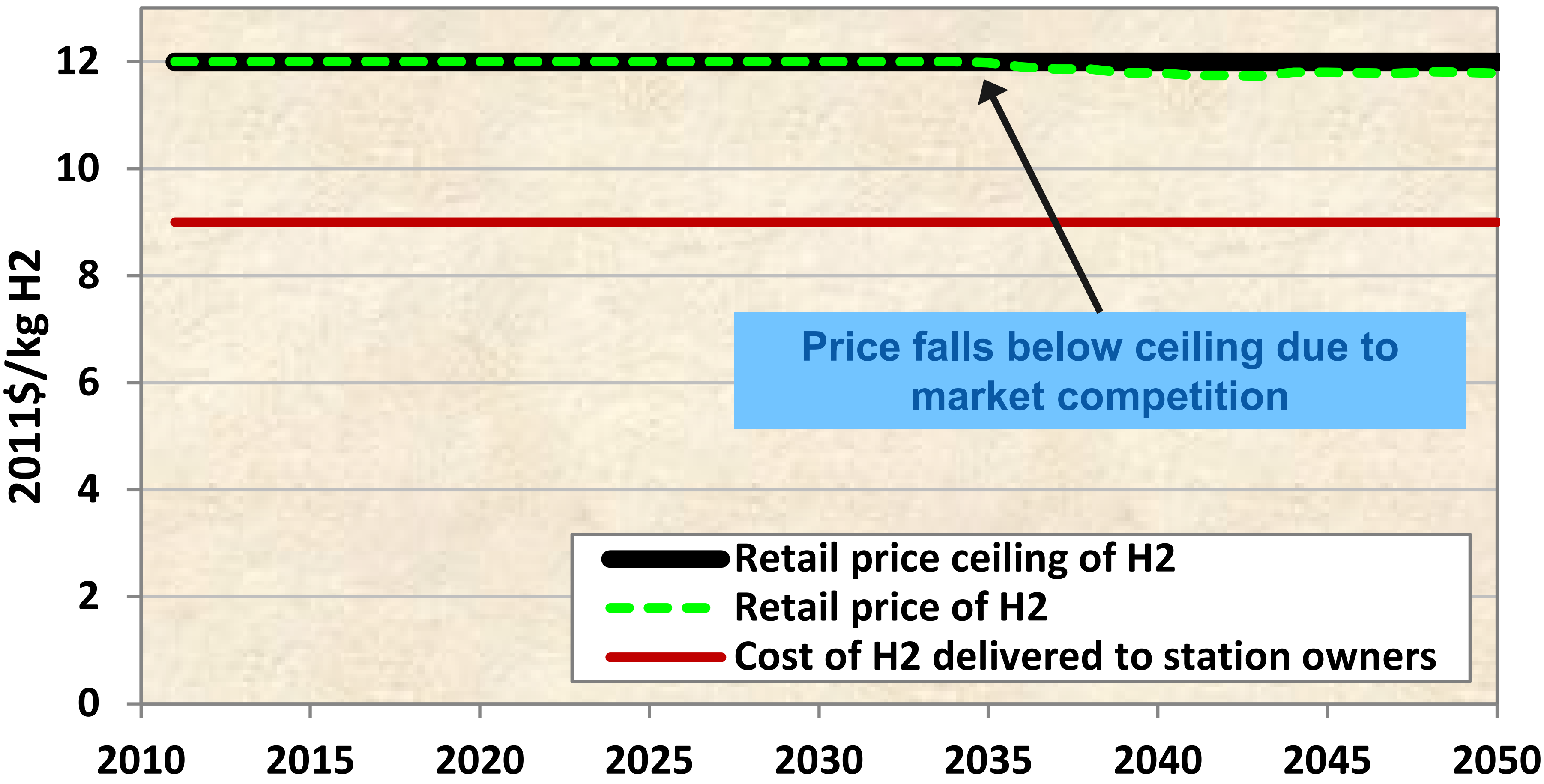
Average vehicle cost (sales-weighted, before incentives)

- 2015 = $87,400
- 2020 = $35,600
- 2030 = $28,300
- 2040 = $28,500
- 2050 = $28,700

ADOPT determines market share based upon price (cost minus incentives and internal subsidies)

Accomplishments: Scenario Analysis Provided

Baseline scenario price ceiling targets parity fuel cost per mile with conventional gasoline vehicles (nominal price of gasoline for Oahu, adjusted by FCEV fuel efficiency)

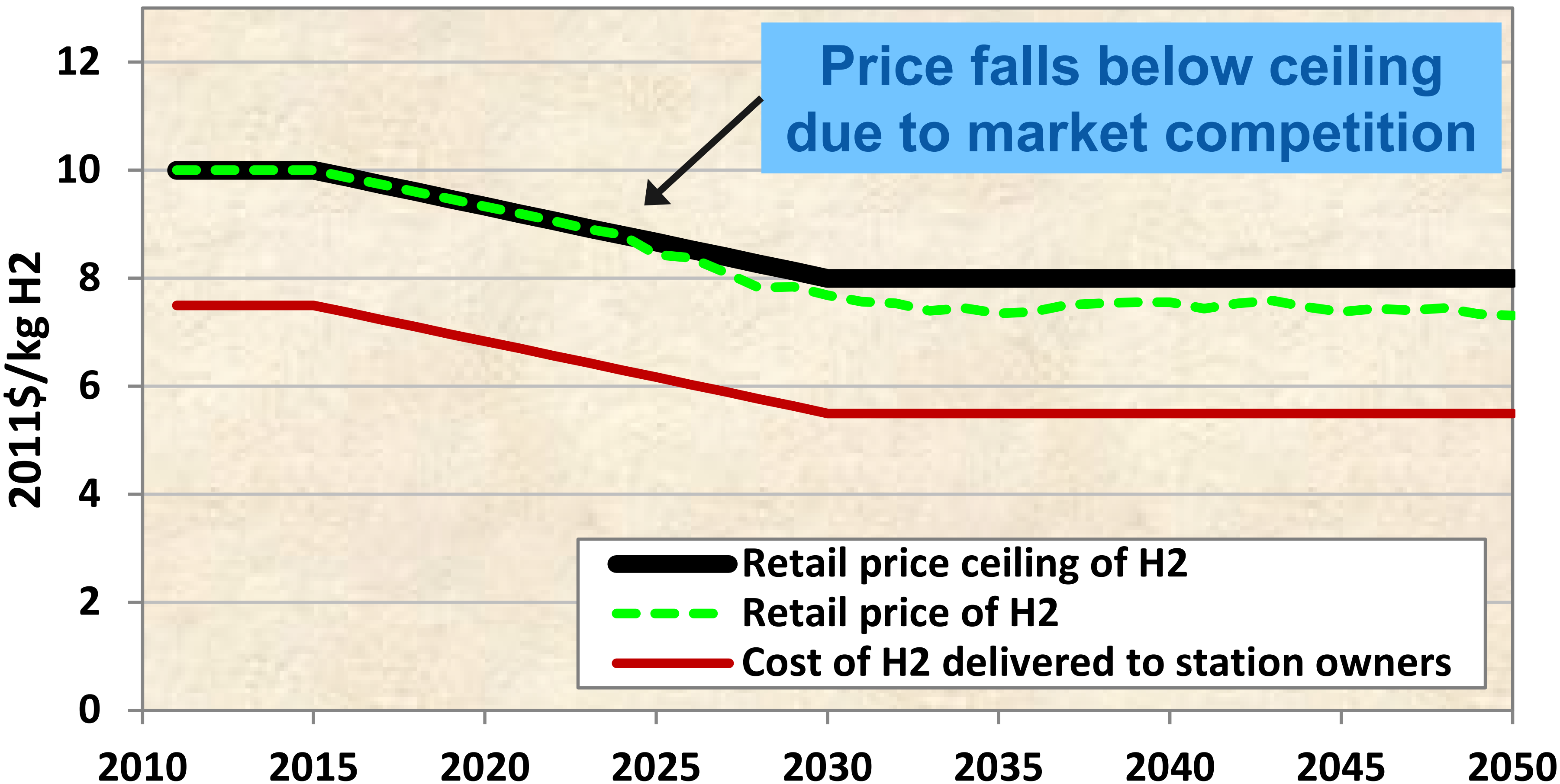


Feedstock Costs:

- Scenario assumes a delivered hydrogen cost of $9/kg to station owner
- Price of electricity = 24¢/kWh

Accomplishments: Scenario Analysis Provided

Optimistic scenario assumes a price ceiling of $8-$10/kg, which is a more competitive price than gasoline, stimulating market adoption

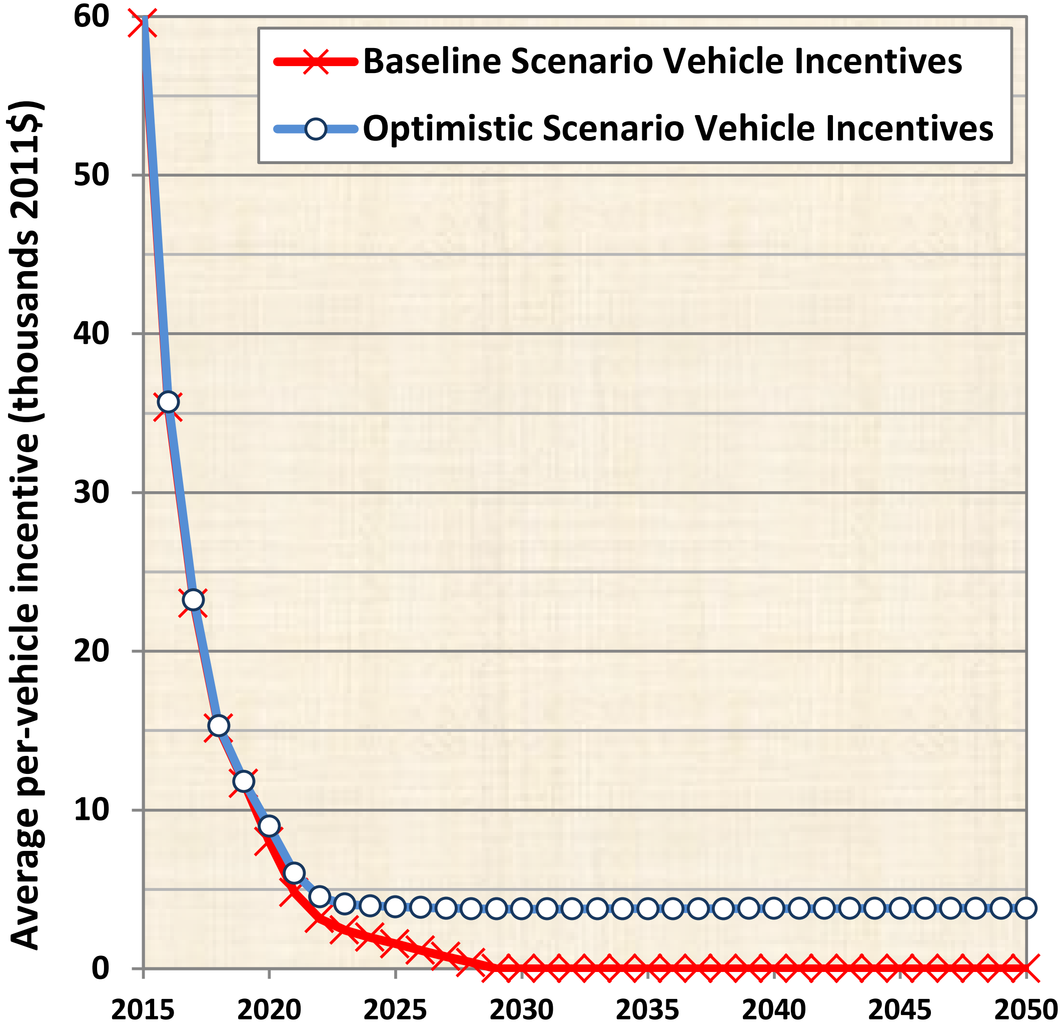


Feedstock Costs:

- Assumption that higher volume production results in lower cost hydrogen
- Price of electricity = 24¢/kWh

Accomplishments: Scenario Analysis Provided

Two levels of vehicle incentives were used for scenario differentiation. More FCEV subsidies drive higher sales and improved station economics.



Incentive sources are not restricted to public subsidies:

- Early adopter subsidization
- Luxury market premium
- "Green" premium
- State & federal incentives
- OEM subsidization

Baseline:

- Full parity with conventional platforms in early years
- Incentives fade out by 2029

Optimistic:

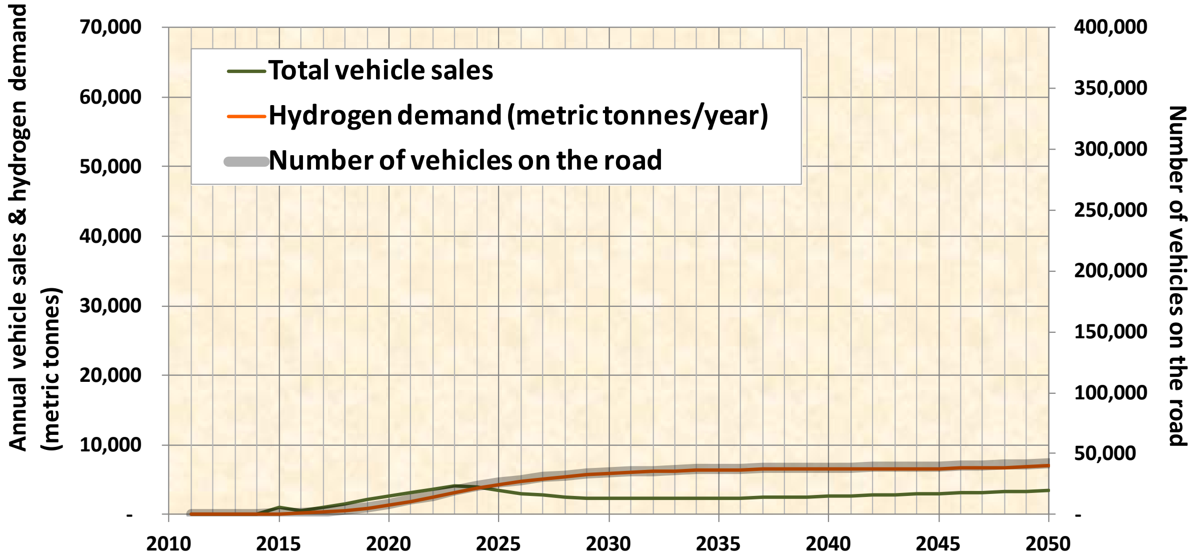
- Full parity with conventional platforms in perpetuity

Vehicle cost source: Transitions to Alternative Transportation Technologies: A Focus on Hydrogen, NRC 2008

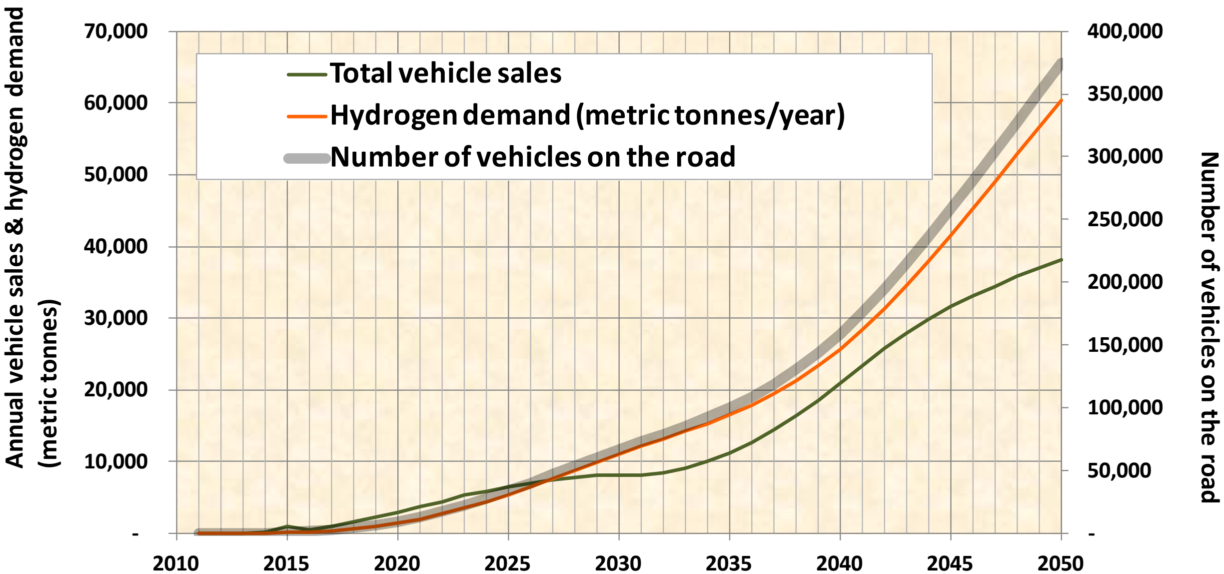
Accomplishments: Scenario Analysis Provided

Vehicle sales projections with ADOPT model. Higher vehicle incentives and cheaper fuel result in higher sales in the optimistic case.

Baseline:
- Full parity with conventional platforms in early years
- Incentives fade out by 2029



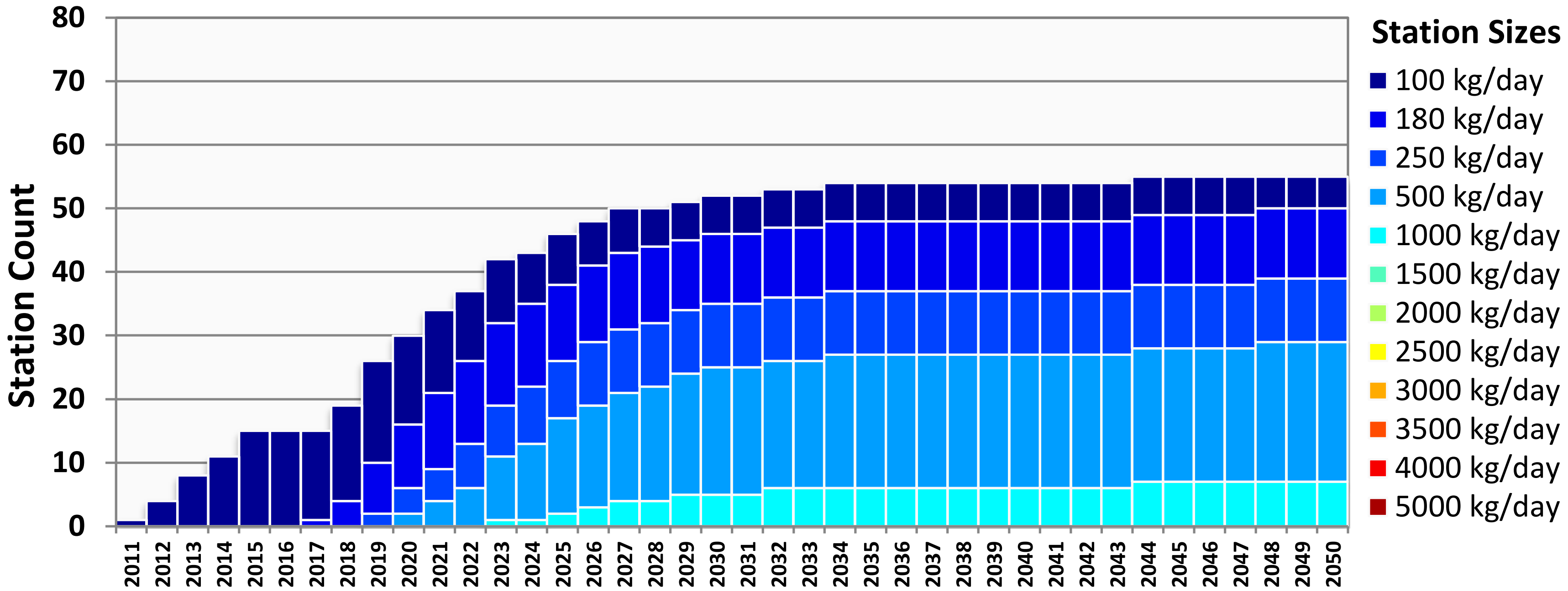
Optimistic:
- Full parity with conventional platforms in perpetuity

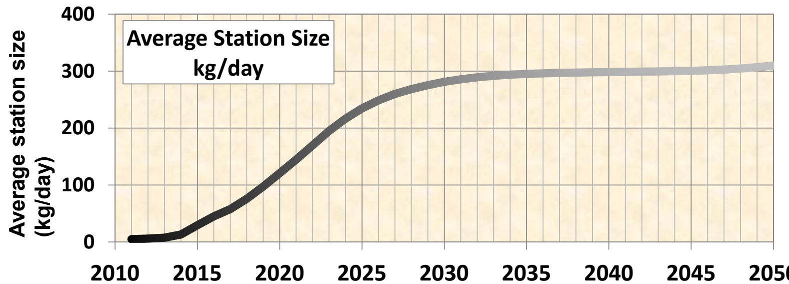


Linear vehicle retirement function used:
4 years = 100% vehicles on road
25 years = 100% vehicles retired

Accomplishments: Scenario Analysis Provided

Scenario station build out projection (Baseline Scenario)
Slower adoption of FCEV results in prevalence of smaller capacity stations.



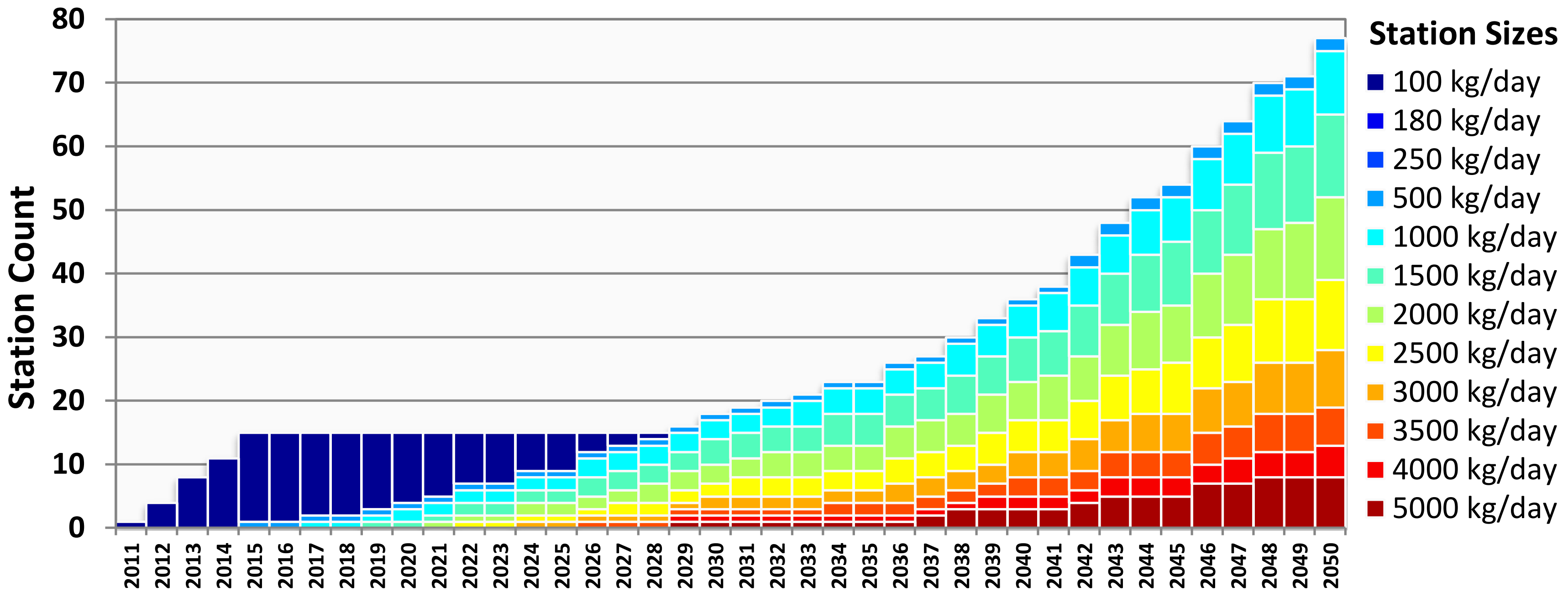


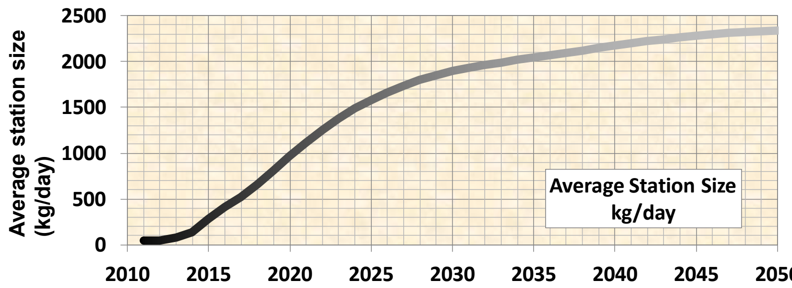
Station abundance by capacity:

- Initial coverage stations = 100 kg/day
- Subsequent stations sizes distributed in lines with gas station distributions

Accomplishments: Scenario Analysis Provided

Scenario station build out projection (Optimistic Scenario)
Accelerated adoption of FCEV provides demand for larger capacity stations.



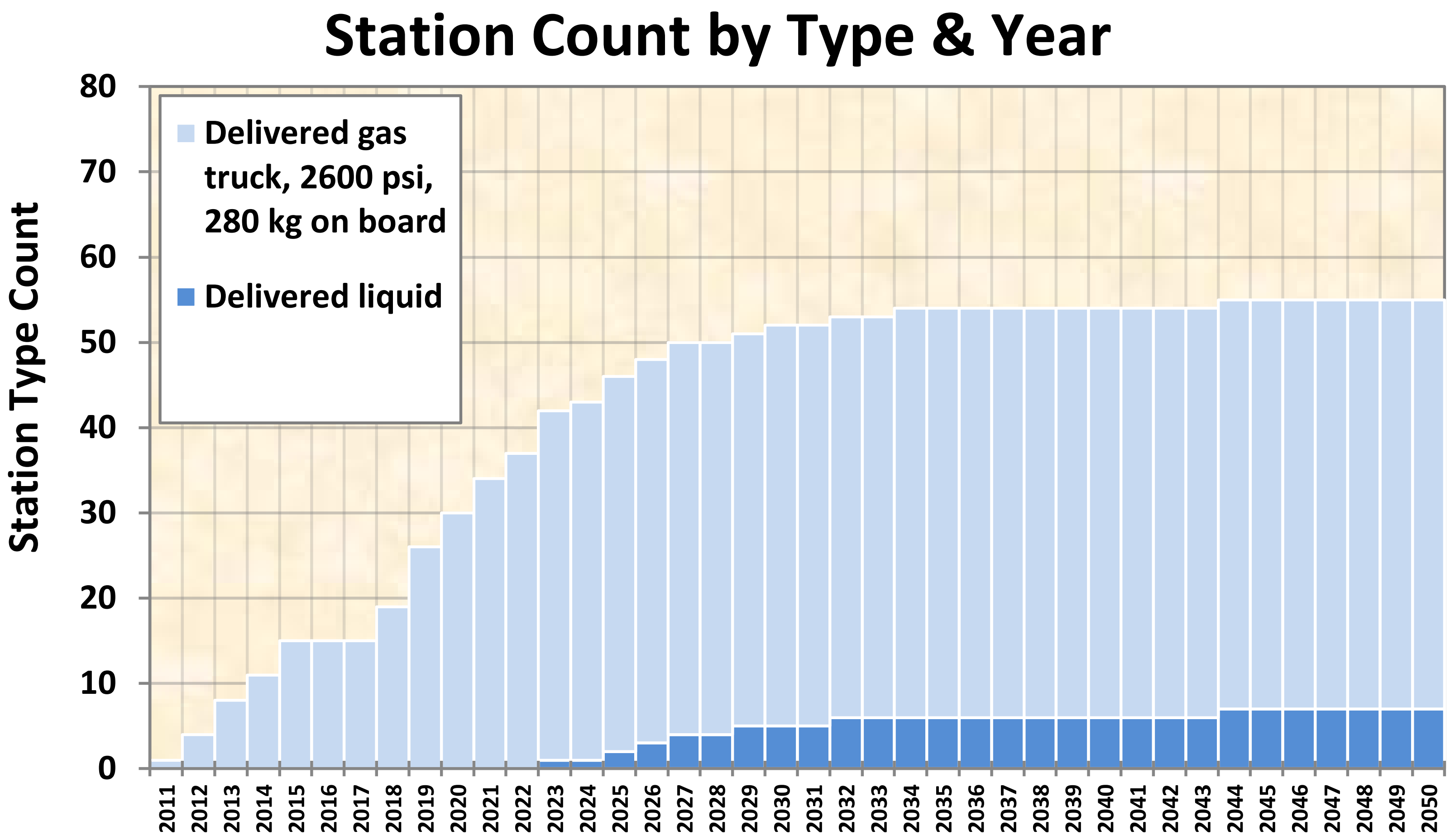


Station abundance by capacity:

- Initial coverage stations = 100 kg/day
- Subsequent stations sizes distributed in lines with gas station distributions

Accomplishments: Scenario Analysis Provided

Scenario station type projection (Baseline Scenario)
Small capacity stations dominate and liquid stations prevail.

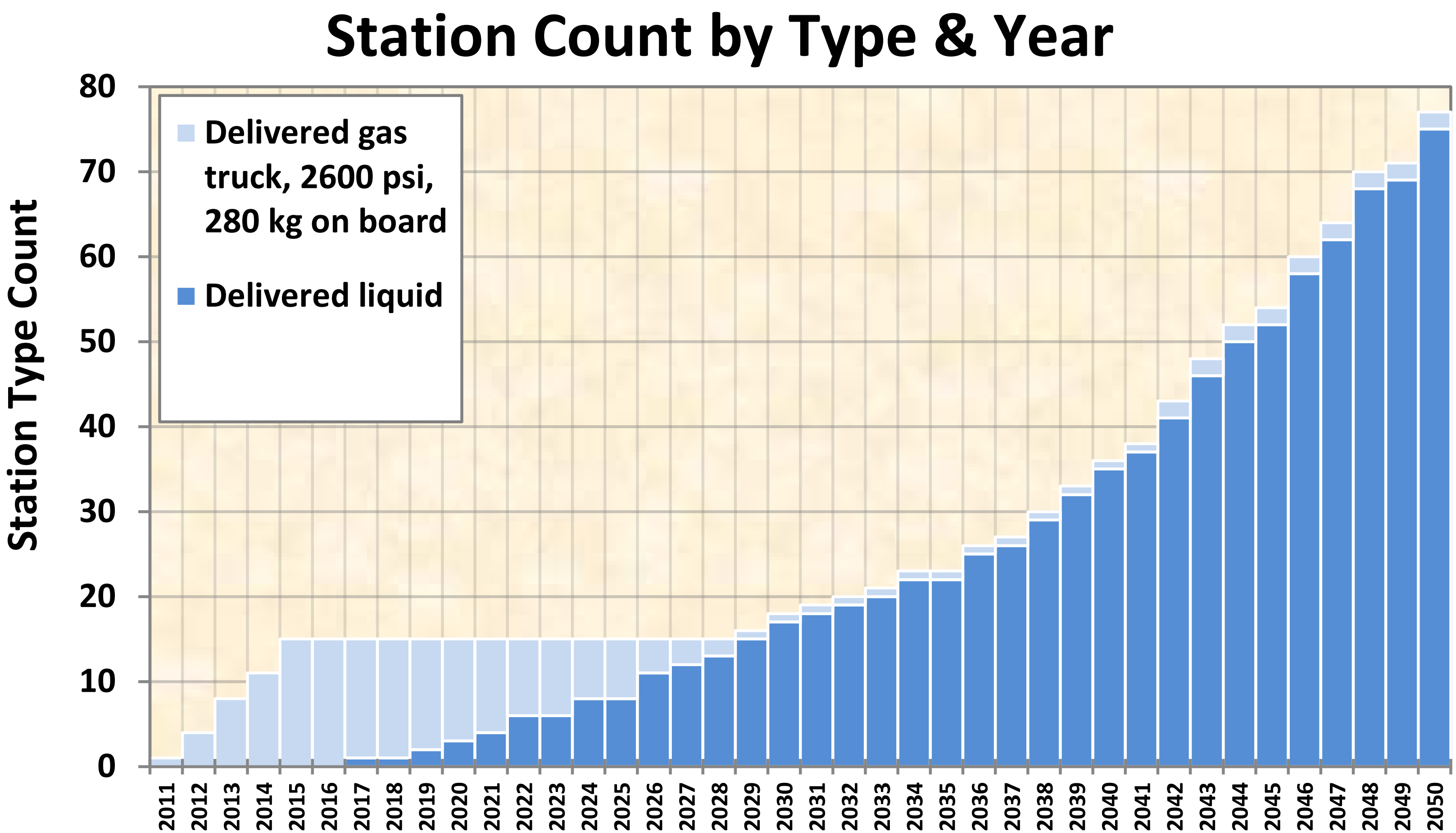


Station types assignments:

- Stations <500 kg/day = gaseous hydrogen delivered to the stations
- Stations >500 kg/day = liquid hydrogen delivery to the stations

Accomplishments: Scenario Analysis Provided

Scenario station type projection (Optimistic Scenario)
Large capacity stations dominate and liquid stations prevail.

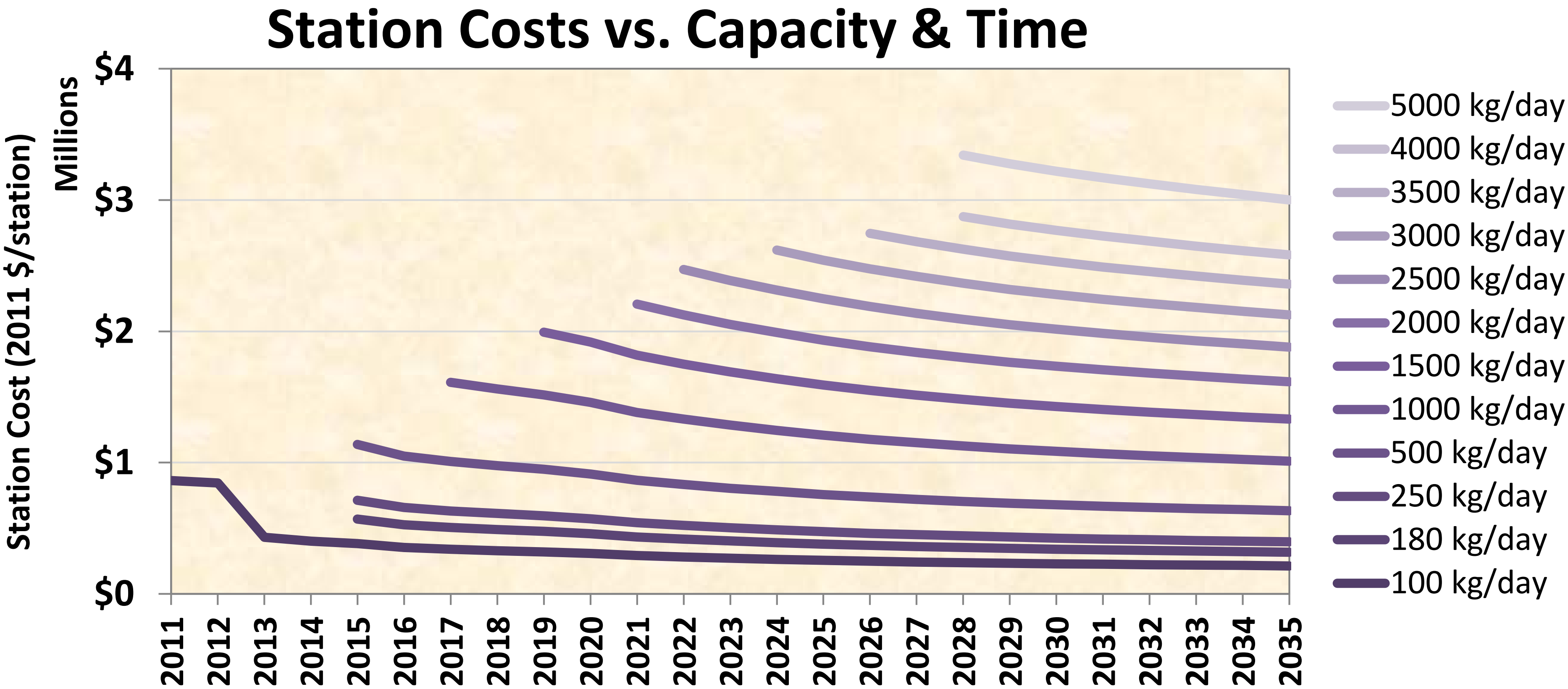


Station types assignments:

- Stations <500 kg/day = gaseous hydrogen delivered to the stations
- Stations >500 kg/day = liquid hydrogen delivery to the stations

Accomplishments: Scenario Analysis Provided

Scenario station cost projections (industry inputs).



Station Costs:

Station costs decrease over time according to world deployment driven learning curves
Station scaling factors are provided from industry partners
Larger stations are cheaper on per-capacity basis (economies of scale)

Accomplishments: Scenario Analysis Provided

Cash flow analysis inputs.
Values are aligned with H2A assumptions

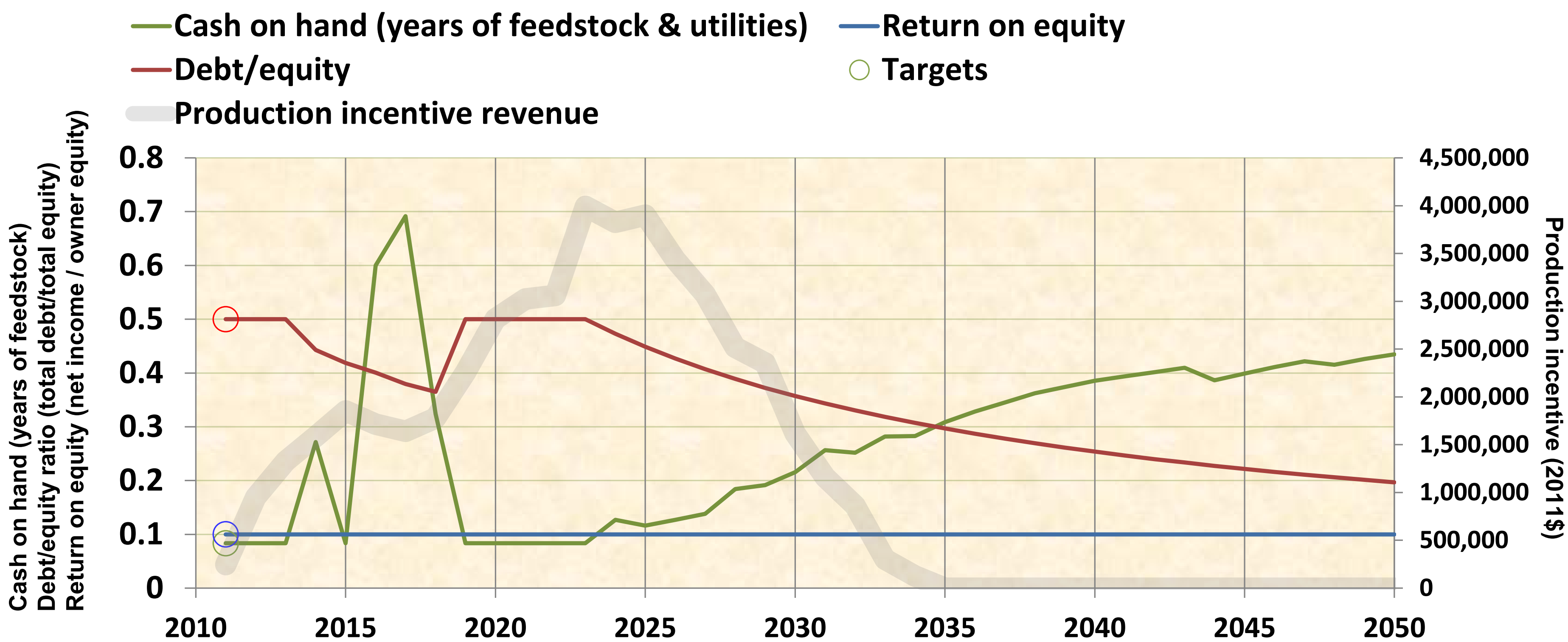
- **Depreciation = 7 years, straight-line**
- **Maintenance as % of contemporary station cost = 2.4%**
- **Labor rate = $40/hr**
- **Credit card fees = $2.5% (flow-through)**
- **Property tax & insurance = 2% of cap cost**
- **Interest on debt = 6%**
- **Total tax rate = 38%**
- **Sales tax = 8% (flow-through)**
- **Sales & administrative expenses = 2%**
- **Licensing & permitting = 1115 $/year**
- **Rent = $3,400**
- **Total capital incentives through 2017 = 15%**
- **Inflation rate = 0%***

- **Target after-tax real IRR = 10% (return on investor equity)**
- **Debt/equity ratio = 0.5 (target)**
- **Cash on hand = 1 month of feedstock & utility expense (target)**

Note: All analysis is performed on real $, 2011 basis
Model can be adjusted to operate with nominal $'s as well

Accomplishments: Scenario Analysis Provided

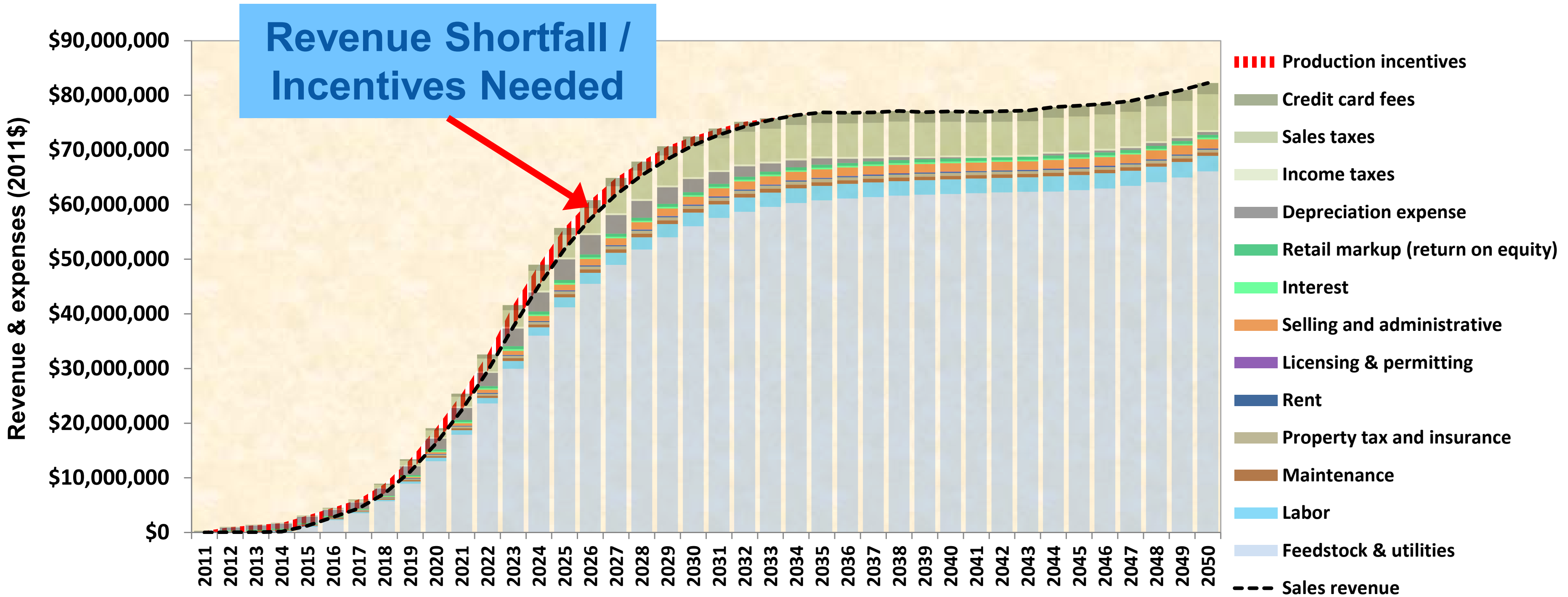
Cash Flow Analysis Results (Baseline Scenario)



- Financial solver determines revenues to produce 10% return on equity
- Debt to equity ratio drops in years when capital is not raised as equity grows
- Cash on hand increases in years of low capital expenditures
- Production incentive needs diminish by 2035

Accomplishments: Scenario Analysis Provided

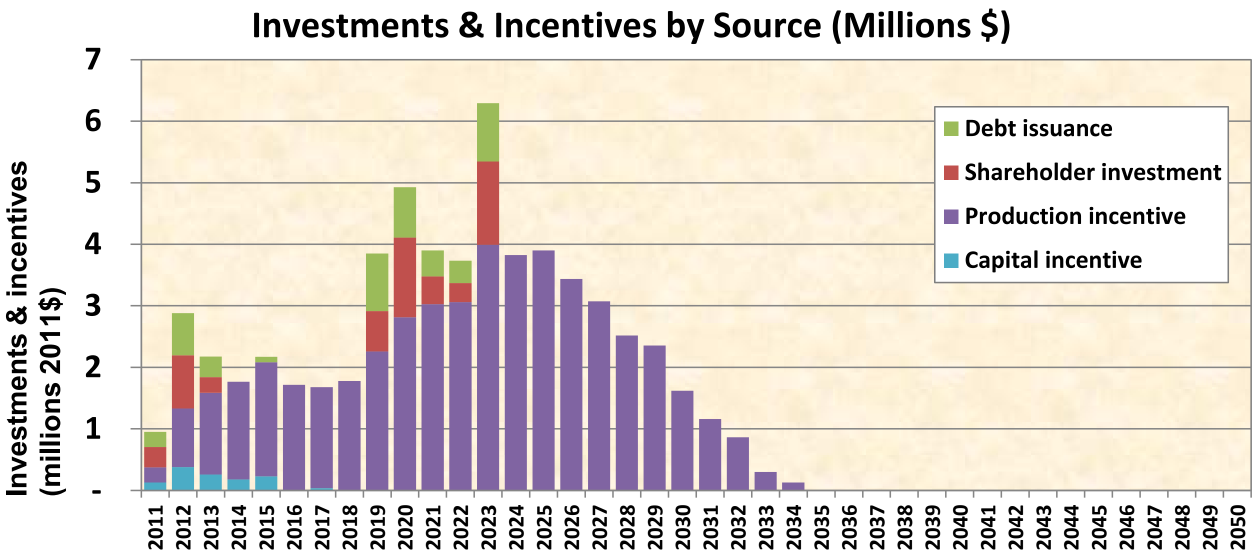
Cash Flow Analysis Results (Baseline Scenario)



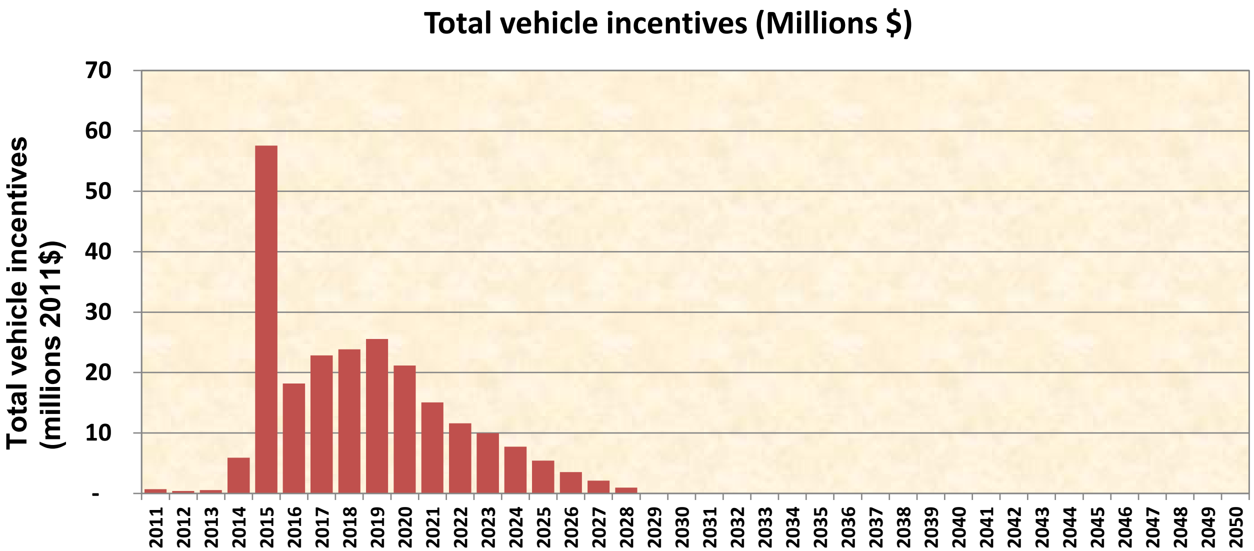
Analysis evaluates required revenue to cover all expenses plus a return on equity. Discrepancy between expenses and realizable revenue is quantified as "production incentive revenue"

Accomplishments: Scenario Analysis Provided

Investment & Incentives (Baseline Scenario)
Vehicle incentives are dominant. Infrastructure incentives diminish by 2035

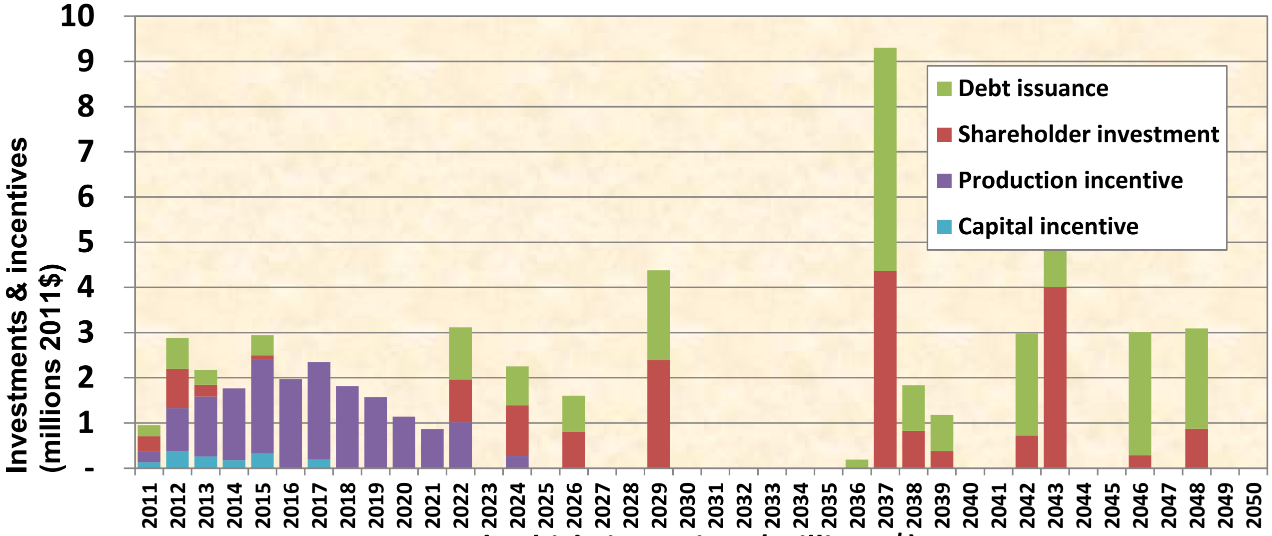


Note: Incentives cover dispensing infrastructure only. No estimates are made at this time for finances of hydrogen production and distribution.

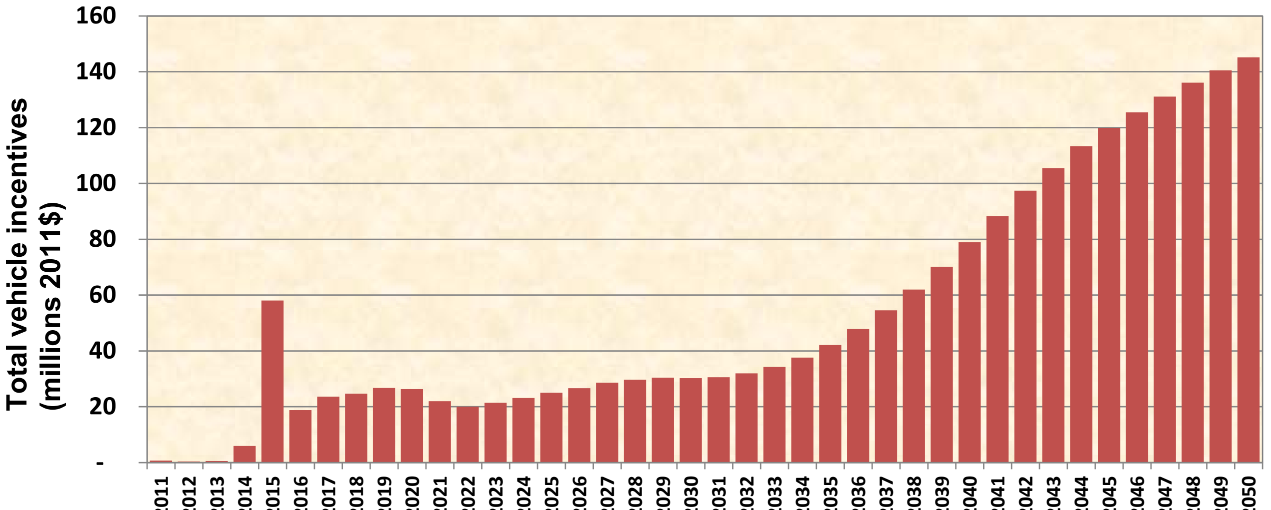


Accomplishments: Scenario Analysis Provided

Investment & Incentives (Optimistic Scenario)
Vehicle incentives are very dominant.
Production incentives are much lower due to higher infrastructure utilization.



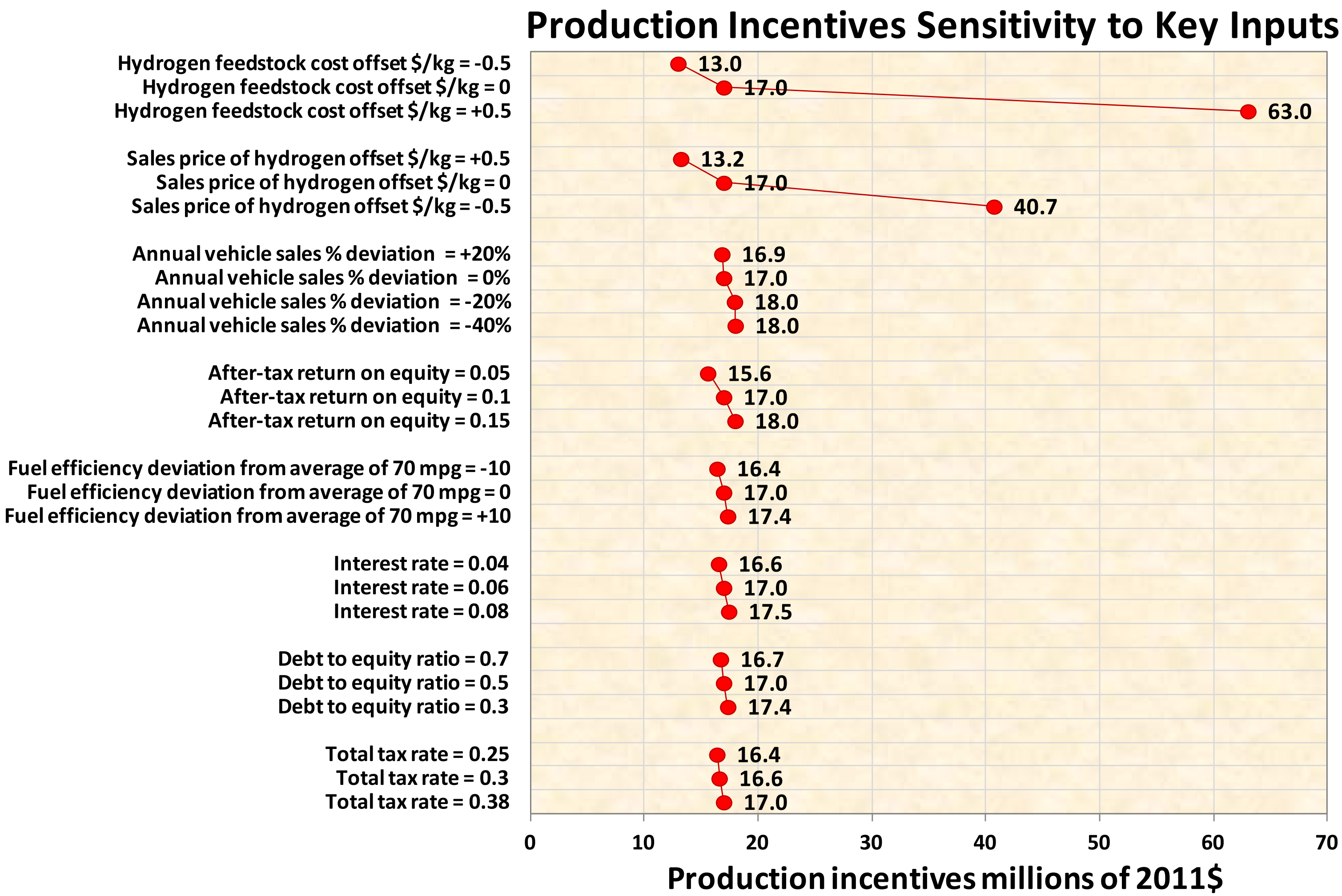
Note: Incentives cover dispensing infrastructure only. No estimates are made at this time for finances of hydrogen production and distribution.



Note: Vehicle incentives continue to increase as total number of vehicles increases.

Accomplishments: Scenario Analysis Provided

**Sensitivity analysis of key cluster variables (Optimistic Scenario)
Model is fully integrated and can be used for risk analysis.**



Note: **Fuel efficiency is one of the most important parameters for infrastructure economics. It is however not shown in this specific sensitivity study.**

Collaborations:

NREL is a member of H2I core analysis team

Core analysis team collaboration:

- Louis Berger [H2I - lead]
- General Motors [FCEV deployment lead]
- U.C. Irvine [station placement analysis]
- Hawaii Gas [gas producer & supplier]
- Wellford Energy [financial modeling oversight]

Extended H2I team members:

- Air Force Research Laboratory
- Aloha Petroleum
- County of Hawaii
- FuelCell Energy
- Office of Naval Research
- Proton Onsite
- State of Hawaii
- TARDEC*
- University of Hawaii
- U.S. Army, Pacific
- U.S. Department of Energy
- U.S. Marine Corps, Pacific
- U.S. Pacific Air Forces
- U.S. Pacific Command
- U.S. Pacific Fleet

* TARDEC = U.S. Army Tank Automotive Research, Development and Engineering Center

Future Work

NREL completed the first phase of support for H2I, and no future work is currently planned.

Modeling algorithms developed for H2I are being used for other hydrogen initiative locations

Algorithms are being integrated into NREL's scenario evaluation, regionalization and analysis (SERA) model.

Additional model features to be added

- **Refinement of geographic dependence of station upgrading**
- **Multi-region analysis (multi-state)**
- **Explicit economics at the individual station level**
- **Refine upgrade frequency (and cost) with industry input**
- **Outputs module for communication with stakeholders**

Summary

NREL produced a detailed deployment and financial model for Hawaii infrastructure deployment.

The financial model has been used to analyze scenarios of stations and fuel cell vehicle penetration and presented to the Hawaii Hydrogen Initiative (H2I).

Key findings:

- **Early coverage stations will experience low capital utilization**
- **Station finances would need subsidies to support capital and operational expenses**
- **Debt and equity investments have a significant place in the early market introduction and subsequent adoption**

Future work:

- **NREL will continue refining and applying station infrastructure algorithms to support future deployment initiatives.**