Analysis of the Hydrogen Infrastructure Needed to Enable Commercial Introduction of Hydrogen-Fueled Vehicles

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H2 Infrastructure Analysis Objectives

- Determine the location and quantity of hydrogen stations that
  - Address the chicken-and-egg infrastructure-vehicle problem
  - Facilitate nationwide interstate travel
  - Minimize costs, maximize impact
  - Lay foundation for widespread commercial introduction of hydrogen vehicles

H2 Infrastructure Analysis Participants and Funding

- Funded by the U.S. Department of Energy's Hydrogen, Fuel Cells & Infrastructure Technologies Program
- Ties into H2 Systems Integration and incorporates various other DOE-sponsored analyses

H2 Infrastructure Analysis Key Assumptions

- Focus on early transition period (2020-2030)
- Light-duty vehicles
- Assumed range ~250 miles
- Drivers willing to travel up to 3 miles from interstate for refueling

H2 Infrastructure Analysis Methodology

1. Identify existing hydrogen production facilities and alternative fuel stations
2. Identify interstate traffic volumes
3. Select specific interstate routes (North-South/East-West)
4. Place stations along interstate routes
5. Estimate station utilization
6. Estimate total network costs

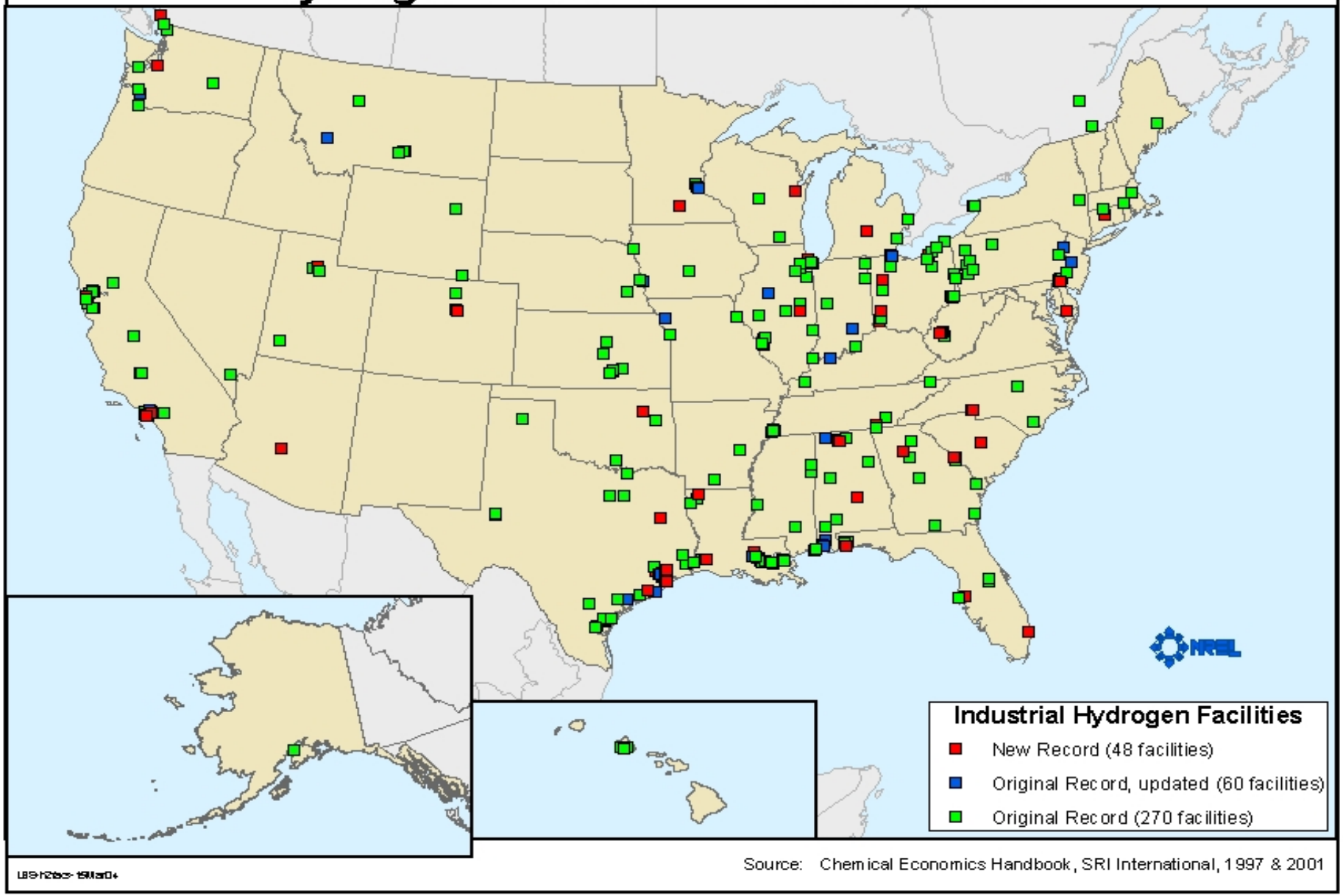
H2 Infrastructure Analysis Methodology

7. Identify Federal Government partners to improve economics and facilitate construction of infrastructure
8. Identify longer-term hydrogen distribution potential

Task 1
Identify Existing Infrastructure

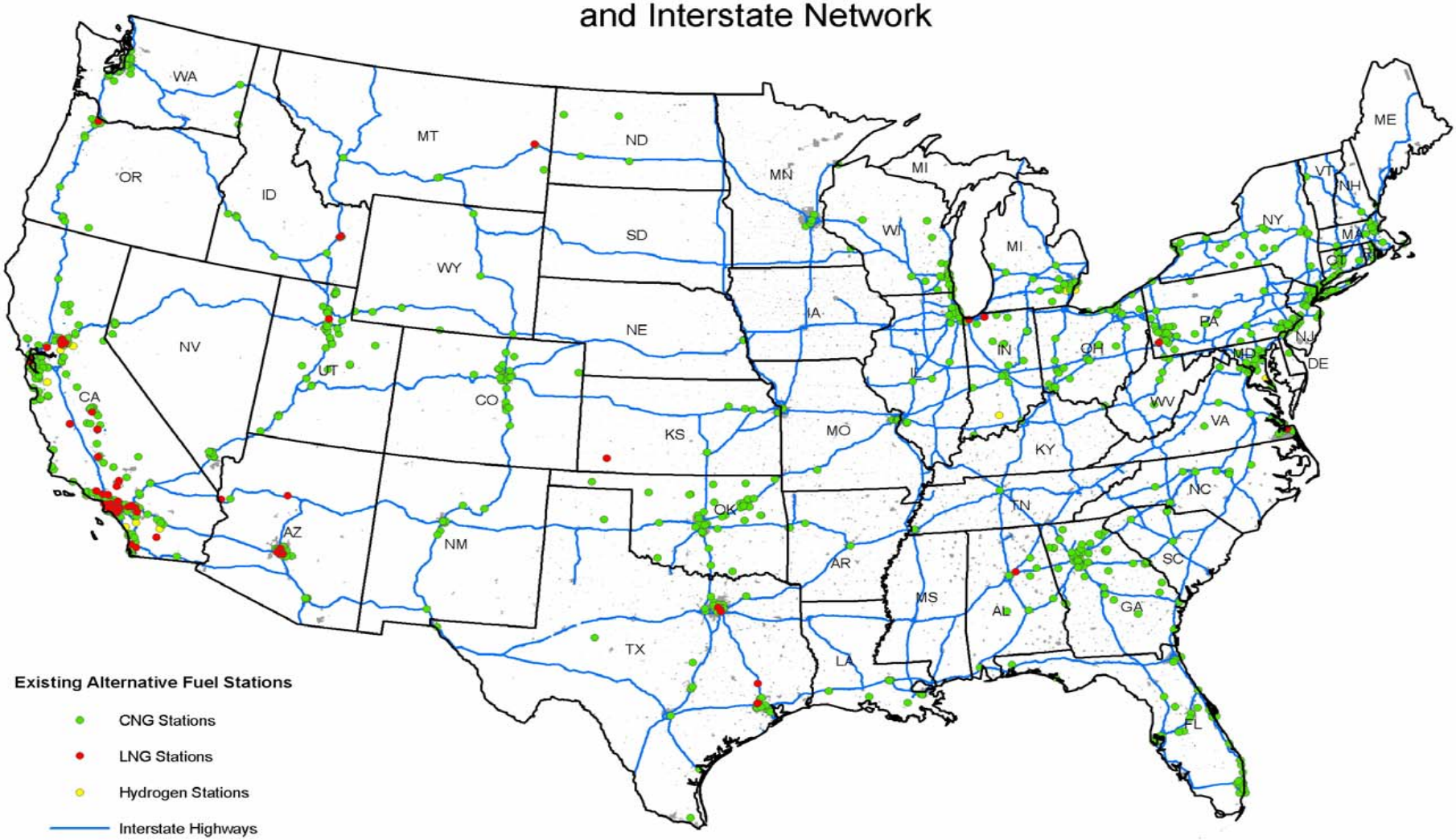
- H2 production facilities
  - Source: Chemical Economics Handbook (1997, 1999, 2001)
- Natural gas and hydrogen stations
  - Source: AFDC Refueling Locator, California Hydrogen Highway Network, Online Fuel Cell Information Resource
- GIS used to provide basis for spatial analysis

Hydrogen Facilities in the United States



Source: Chemical Economics Handbook, SRI International, 1997 & 2001

Existing CNG, LNG, Hydrogen Fuel Stations and Interstate Network



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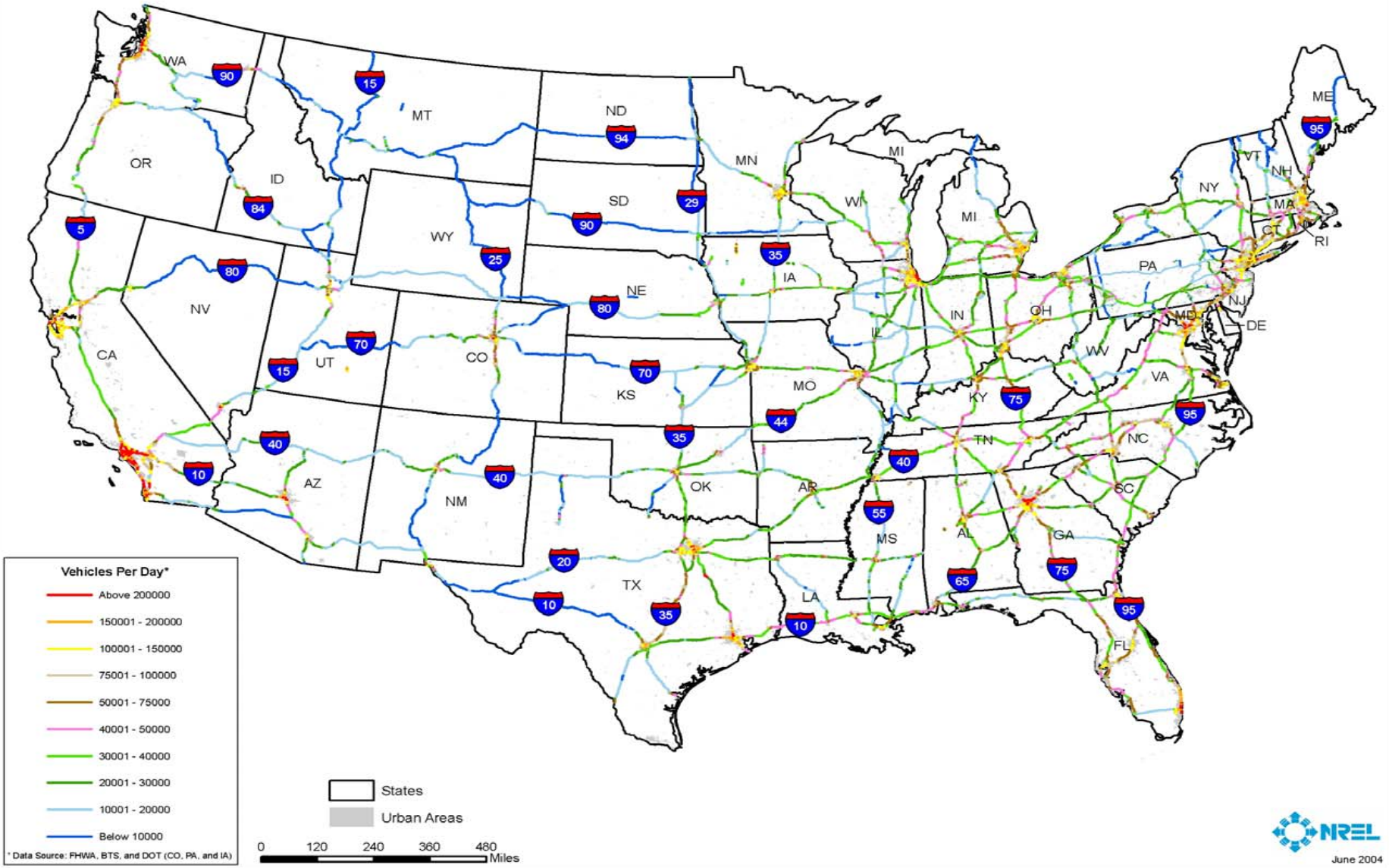
Task 2
Identify Interstate Traffic

- Identified sources of traffic data
  - USDOT Bureau of Transportation Statistics
  - USDOT Federal Highway Administration
  - Individual state DOT
- Selected FHWA data
- Incorporated data into GIS

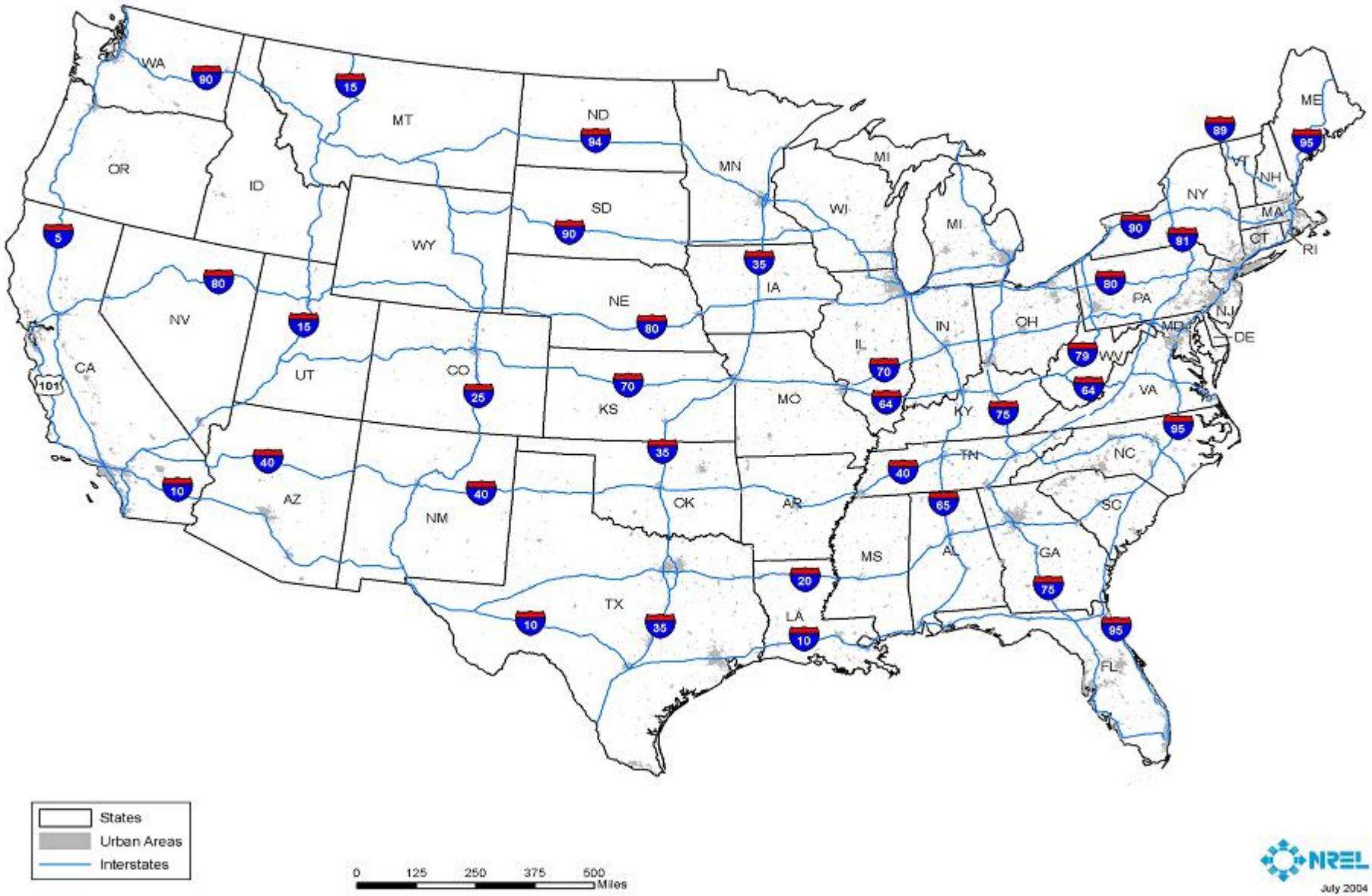
2002 Annual Average Daily Traffic



Task 3
Select Interstate Routes

- Selected a subset of interstates that constitutes a comprehensive network
  - Facilitates cross-country travel
  - Accessible to the most drivers
  - Incorporates every state
  - Incorporates major metropolitan areas

Proposed Interstate Routes for Hydrogen Refueling Infrastructure



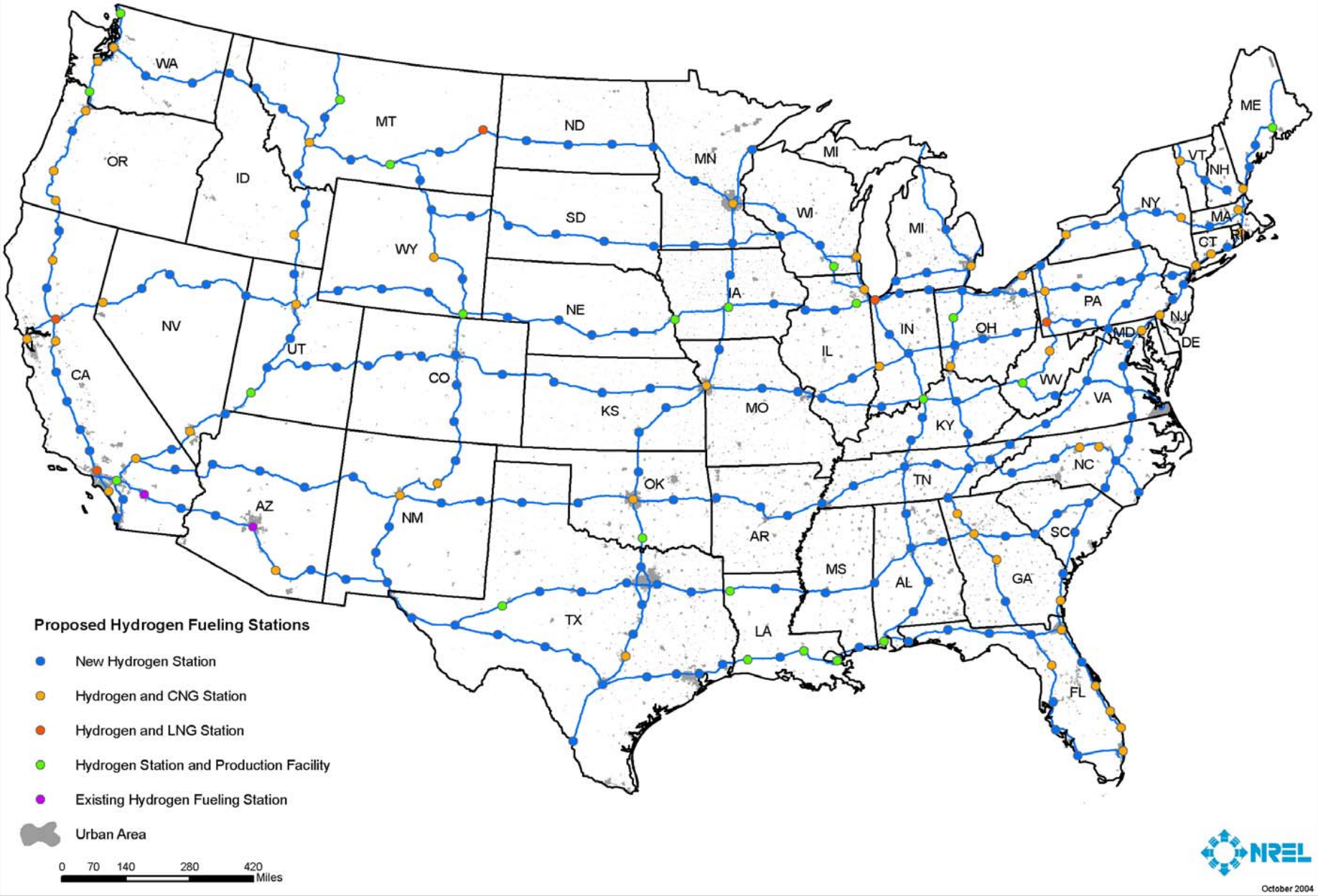
Task 4
Place Stations Along Routes

- Used GIS to incorporate all information
  - LNG/CNG stations
  - Hydrogen stations
  - Hydrogen production facilities
  - Population
  - Interstate network
  - Distance between stations

Task 4
Place Stations Along Routes

- Placed stations
  - Considering all factors
  - Manually selected data
  - 100 miles apart in the west
  - 50 miles apart in the east
  - Maximize use and coverage

Proposed Hydrogen Fueling Stations Along Major Interstates



Interstate	Mileage	Number of Stations	Existing Natural Gas Stations	Existing H2 Stations	Sites Near H2 Production Facilities	New Stations Needed
5	1,381	20	10	0	2	8
10	2,460	29	1	2	5	21
15	1,434	17	5	0	3	9
20	1,539	18	1	0	2	15
25	1,063	13	3	0	1	9
35	1,568	18	4	0	2	12
40	2,555	28	5	0	0	23
64	938	7	0	0	2	5
65	887	11	1	0	1	9
70	2,153	23	3	0	0	20
75	1,786	19	6	0	1	12
79	343	5	3	0	1	1
80	2,900	33	6	0	4	23
81	855	9	0	0	0	9
89	191	3	1	0	0	2
90	3,021	35	7	0	2	26
94	1,585	16	6	0	0	10
95	1,920	30	13	0	1	16
Total Mileage	28,580					
Total Stations		284	58	2	22	202

Task 5
Estimate Station Utilization

- Predict station utilization rate
  - Go Your Own Way (GYOW) estimates for vehicle penetration
  - 50% of passenger fuel cell vehicles passing station stop to use it in 2020
  - 91% of traffic light-duty passenger vehicles
  - 3 kg standard vehicle fill

Task 5
Estimate Station Utilization

"Go Your Own Way" Estimates for Vehicles on the Road

Year	**LD H2 FCV stock (M)**	**Total LDV stock (M)**	**FCVs as % of stock**
2020	3	274	1.1%
2030	59	306	19.4%
2040	140	328	42.8%
2050	175	353	49.5%

- Rapid pace of technological innovation
- High level of environmental responsiveness

Task 5
Estimate Station Utilization

Sample: Colorado Stations Summary

Station	Interstate	AADT	FC Vehicles Using Station	H2 Demand (kg)
Flagler	70	3569	17	52
Walsenburg	25	6006	29	88
Grand Junction	70	14858	72	217
Vail	70	16286	79	237
Glenwood Springs	70	19612	95	286
Colorado Springs	25	35271	171	514
Denver	25, 70	60084	292	876

Assumes 3kg fill up, 50% of vehicles stop at station, President's H2 initiative penetration estimates for year 2020

Task 6
Estimate Total Network Costs

- Select station design for each station
  - Incorporate existing infrastructure
    - Natural gas stations
    - H2 stations or facilities
  - Based on H2 demand at each location
  - Use UC-Davis estimates for station capital costs

Task 6
Estimate Total Network Costs

Station Type	Cost per Station ($M)
Steam Methane Reformer, 100	1.05
Steam Methane Reformer, 1000	5.14
Electrolyzer, grid 30	0.55
Electrolyzer, grid 100	0.92
Electrolyzer, renewable, 30	0.62
Mobile Refueler	0.24
Delivered LH2, 1000	2.68
Pipeline Delivered	0.58

Conditions for Assigning Station Types		
Existing Infrastructure	**Volume of H2 (kg/day)**	**Station Type**
CNG	<30	Mobile
LNG	<30	Mobile
HF	<30	Pipeline
H2	<30	No Change
None	<30	E30
CNG	30-100	SMR100
LNG	30-100	SMR100
HF	30-100	Pipeline
H2	30-100	No Change
None	30-100	E100
CNG	100-1000	SMR100/SMR1000
LNG	100-1000	SMR1000
HF	100-1000	Pipeline
H2	100-1000	No Change
None	100-1000	Delivered LH2
CNG	>1000	SMR1000
LNG	>1000	Delivered LH2
HF	>1000	Pipeline
H2	>1000	No Change
None	>1000	Delivered LH2

Task 6
Estimate Total Network Costs

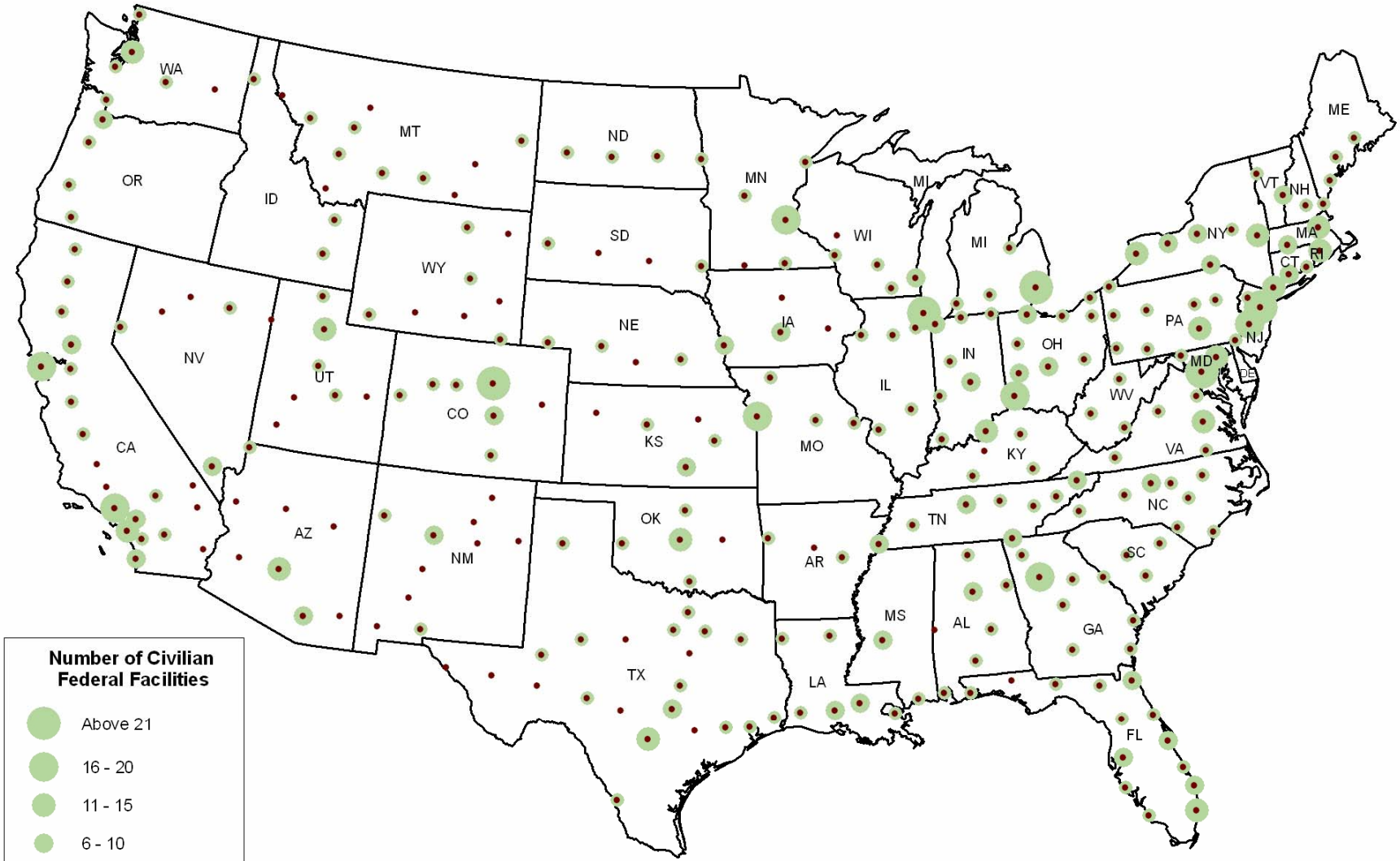
- 2020 Station Costs: $1.1B
  - General Motors estimate: $11.7B
  - NREL spreadsheet analysis (urban focus): $5B-$10B

Station Type	Quantity
SMR1000	48
SMR100	7
Pipeline	22
No Change	2
E100	19
Delivered LH2	186

Task 7
Identify Federal Govt. Partners

- Federal Executive Order 13149 requires federal fleets to purchase AFVs and reduce petroleum consumption
  - H2 vehicles qualify as AFVs
  - H2 displaces 100% petroleum for every “gallon” used
- Federal fleets also represent co-generation and public fueling opportunities

Civilian Federal Facilities within 10 Miles of a Proposed Hydrogen Station



80% of the Proposed Hydrogen Refueling Stations Have at Least One Civilian Federal Facility within 10 Miles

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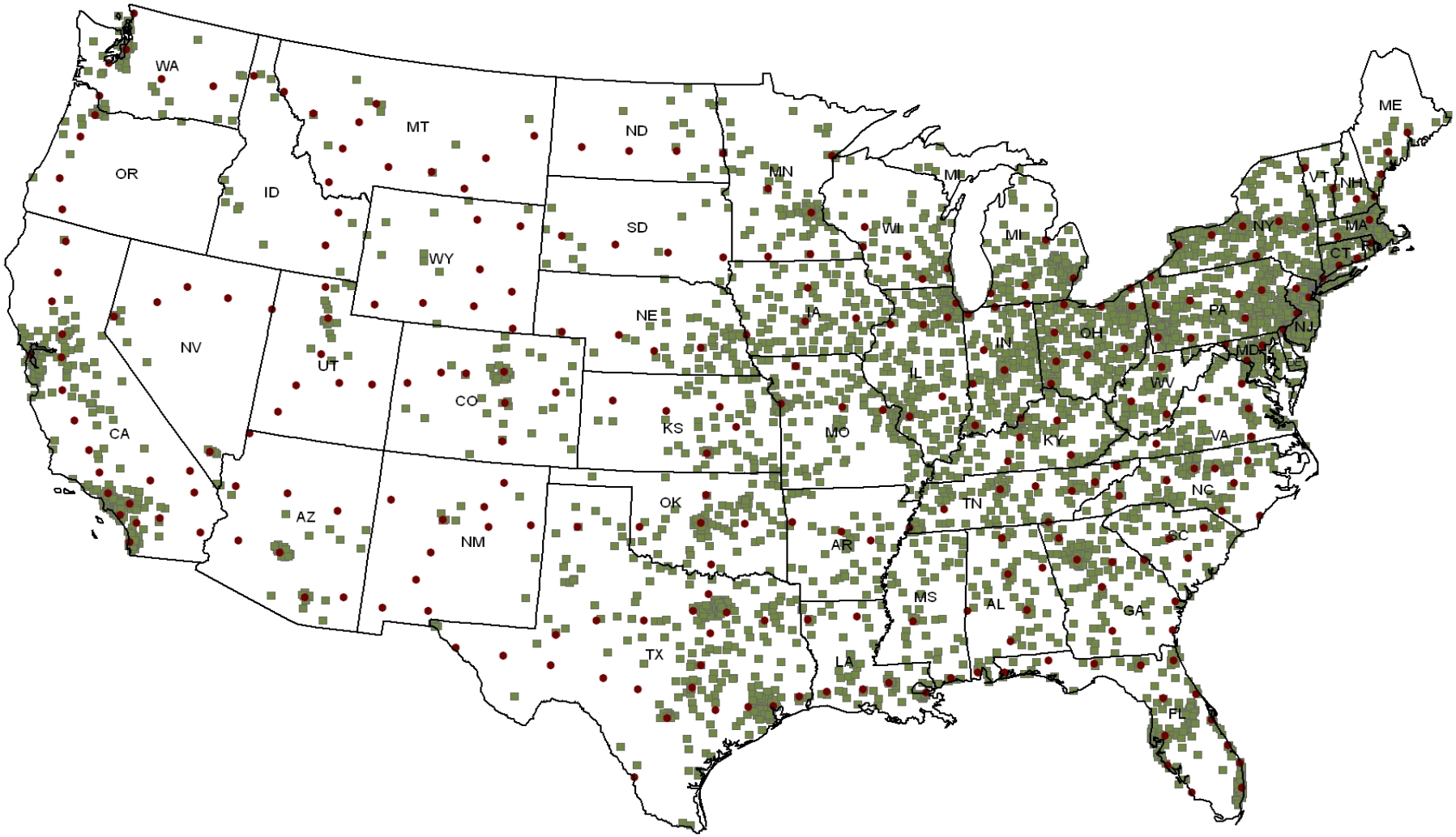
USPS Fleet Statistics

Fiscal Year	Light-duty vehicle acquisitions	Total AFVs and other credits	Total inventory of light-duty AFVs
FY1996	10,071	2,656	6,748
FY1997	2,916	825	7,653
FY1998	12,223	10,767	18,397
FY1999	13,865	13,267	31,560
FY2000	2,838	2,452	33,554
FY2001	1,405	1,189	31,110
FY2002	855	641	32,001
FY2003	9,197	7,861	37,573

Proposed Hydrogen Fueling Stations in Relation to USPS Facilities



- Proposed Hydrogen Fueling Stations
- USPS Facilities

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Conclusions

- 284 stations identified to make up potential transition hydrogen fueling infrastructure backbone
- Assumes 1% fuel cell vehicles in 2020, 20% in 2030, 50% in 2050
- $1.1B construction cost to support 2020 demand
- Federal facilities could play key role in making H2 stations available in near term

H2 Infrastructure Analysis Future Work

- Expand to urban analysis, with primary focus on key metropolitan areas (Clean Cities, population, air quality, etc.)
- Improve utilization/hydrogen demand estimates
- Identify co-generation options for federal facilities
- Tailor station types to available renewable resources

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For More Information

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