US HYDROGEN INDUSTRY ROADMAP

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About the Fuel Cell and Hydrogen Energy Association (FCHEA)

- FCHEA if the leading Industry Association for Fuel Cells and Hydrogen in the US

- FCHEA represents over 60 leading companies and organizations that are advancing innovative, clean, safe, and reliable energy technologies.

- FCHEA drives support and provides a consistent industry voice to regulators and policymakers. Our educational efforts promote the environmental and economic benefits of fuel cell and hydrogen energy technologies.

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Fuel Cell & Hydrogen Energy Association

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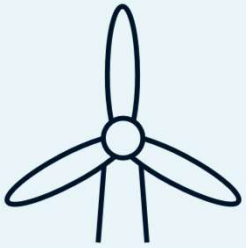
he US industry road
ap lays out a 10-year
lan to develop
hydrogen economy

Today	2022	2025	2030
Immediate next steps	Early scale-up	Diversification	Broad rollout

U.S. H_2Road Map

Benefits of Hydrogen

onomic growth
d employment



Resiliency and
reliability

Reduction in local
air pollutants

Reduction in
greenhouse gas

5 Uses of Hydrogen

er generation and balancing

ralized power
ding storage) and
puted power (off-
backup power)

ogen as an energy
er and storage
um

Transportation
(including materi
handlings, light-
and heavy- duty
vehicles, captive
fleets, rail)

Fuel for **residential and commercial buildings** (including blending into th
grid, combined heat and p

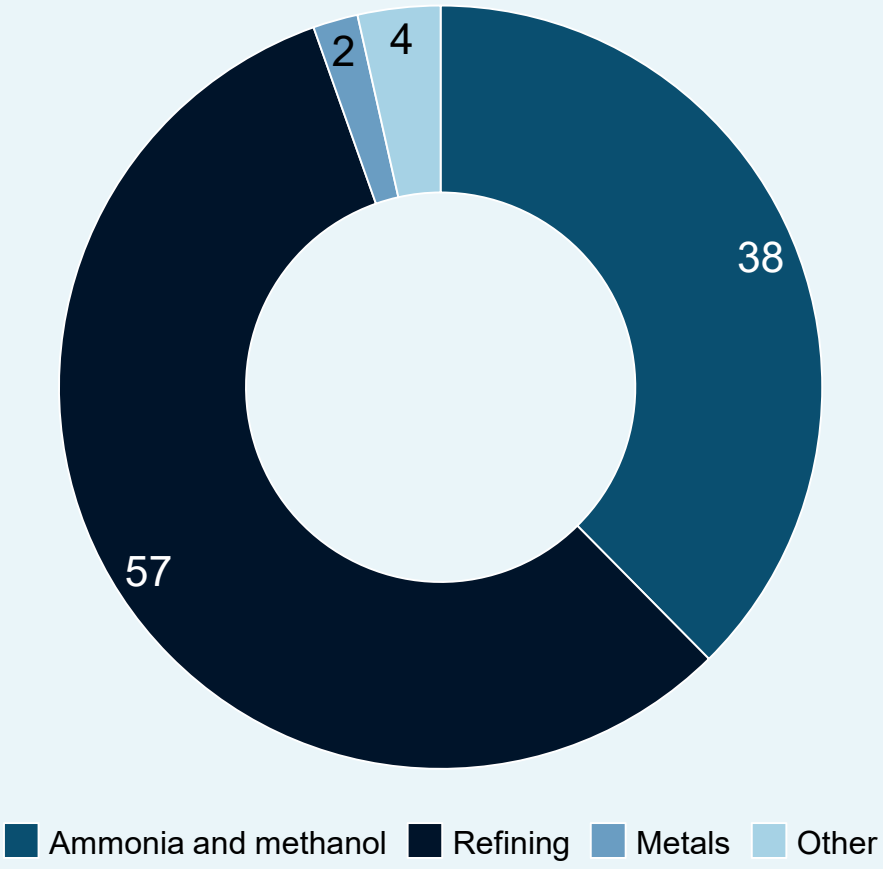
Fuel for **industry**

Feedstock for industry (ammonia, methanol, refineries, steel) and long-distance transport (aviation, marine)

U.S. H_2Road Map

US Hydrogen Market Today

Current consumption in the US H2 market
Percent



11.4 m metric tons

of H_2 is currently consumed annually in the US market

~$17.6 bn

total value of the H_2 market in the US today[1]

77%

steam methane reforming H_2

23%

by-product H_2 from refining

ming realized price of $2/kg for hydrogen produced from steam methane reforming (SMR)

Transition to ‘low-carbon hydrogen’

Water electrolysis using low-carbon electricity (e.g., nuclear, solar, wind)

Reformer-based hydrogen with carbon capture and storage (CCS) or renewable natural gas (RNG) feedstock

Direct gasification of waste including municipal and agricultural

By-product hydrogen recovered from other industrial processes

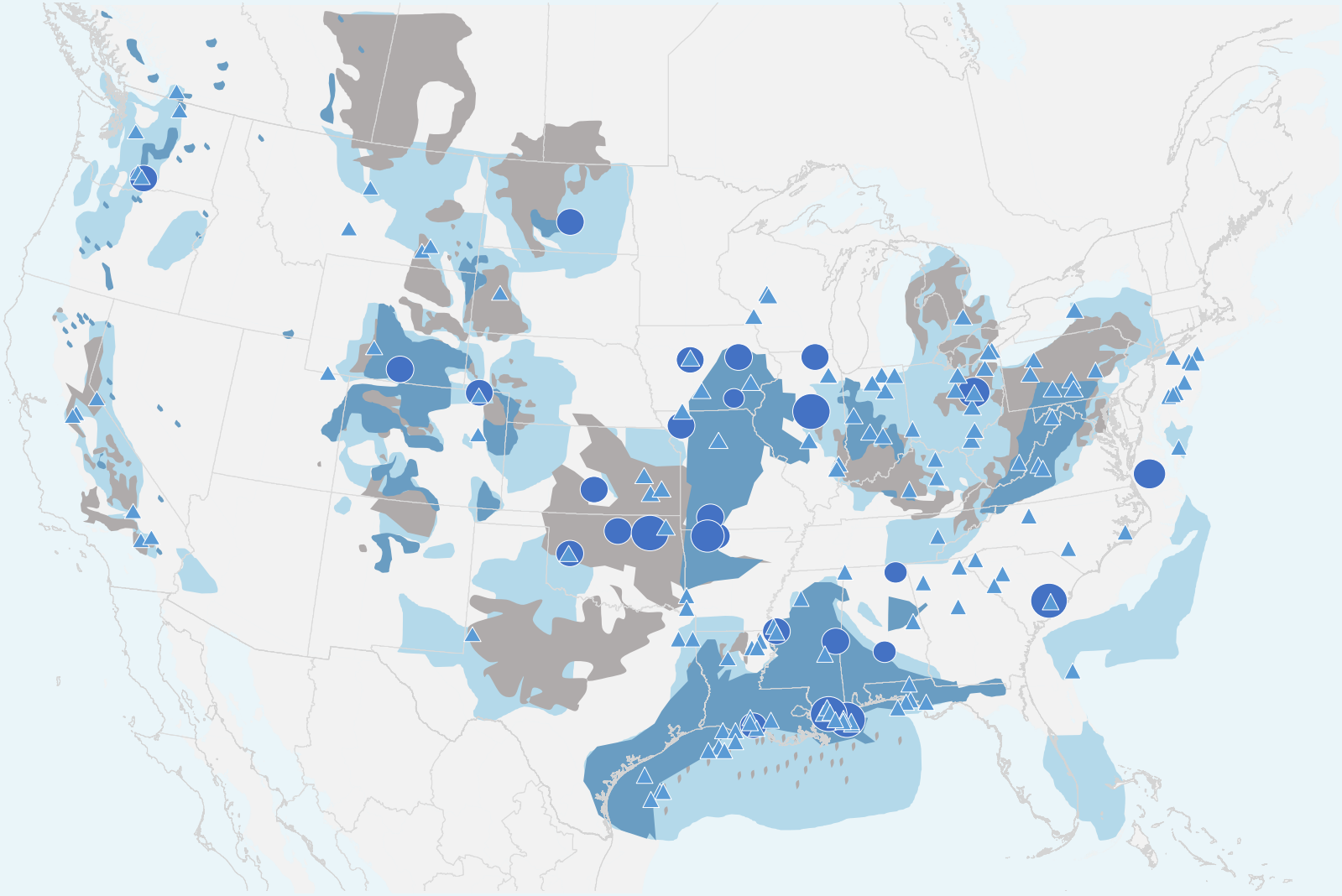
This effort has adopted a **pathway agnostic** approach

Low-carbon hydrogen”

ydrogen produced from ow carbon production pathways

n the US, carbon capture may also enable low-carbon hydrogen

Carbon capture and storage (CCS) locations in the US



Saline formations

Unmineable coal areas

Oil and gas reserv

Existing hydrogen plant

Existing ammonia plant

Ammonia capacity

Thousand tons/year

- 0-250
- 250-500
- 500-750
- >750

ary F. Teletzke, Evaluation of Practicable Subsurface CO2 Storage Capacity and Potential CO2 Transportation Networks, Onshore North America, nhouse Gas Control Technologies Conference, Melbourne, October 21-26 2018 (GHGT-14).

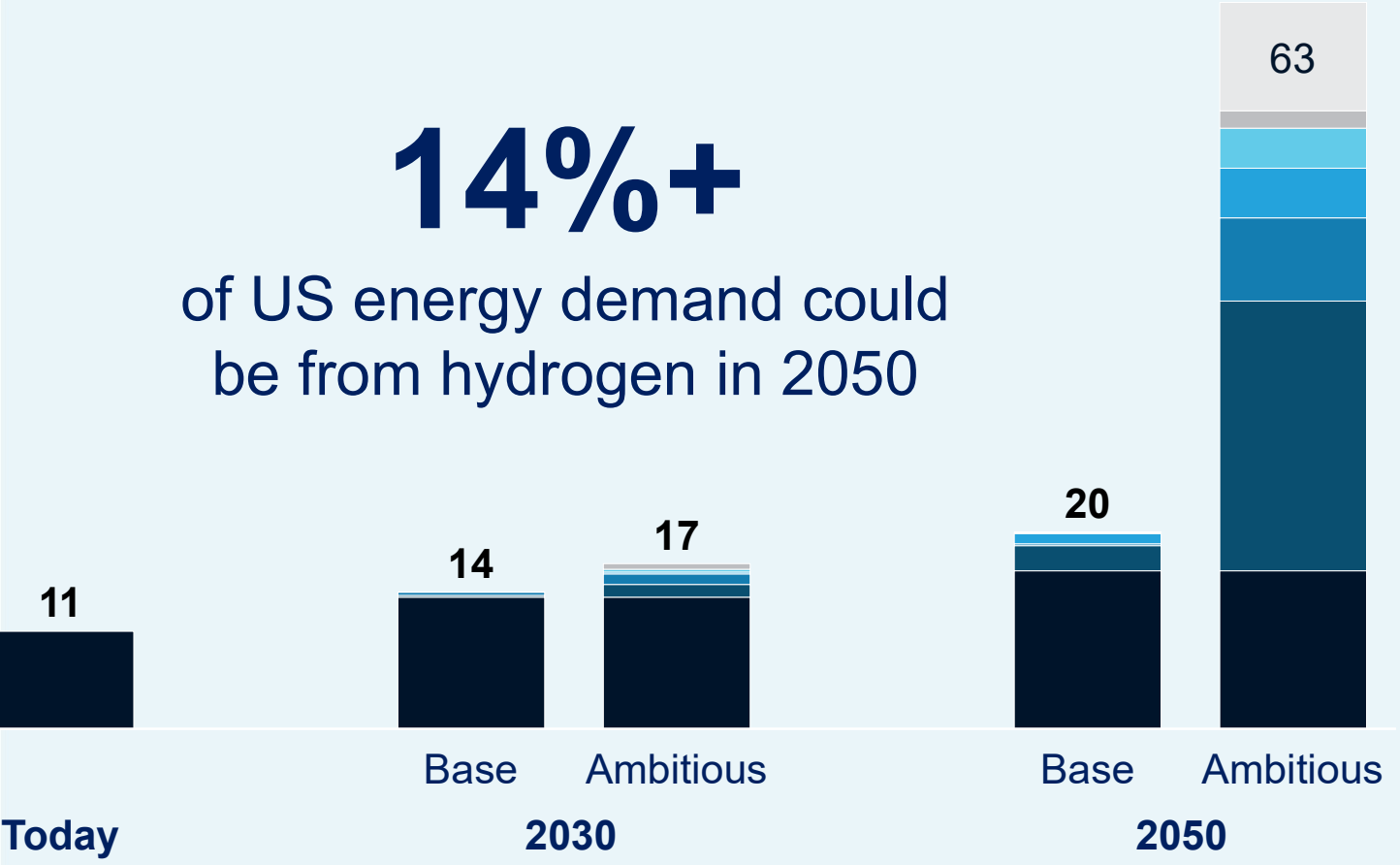
U.S. H_2Road Map

he road map lays out a high-growth pathway for hydroge

illion metric tons per year

14%+

of US energy demand could be from hydrogen in 2050



- Additional upside from other uses
  - Synthetic jet fuel
  - Ammonia as fuel for shipping
- New feedstock
- Power generation and grid balanc
- Fuel for industry
- Fuel for residential and commerci buildings
- Transportation fuel
- Existing feedstock

d excluding feedstock, based on IEA final energy demand for the US
ng that 20% of jet fuel demand would be met from synthetic fuel and 20% of marine bunker fuel from ammonia
e numbers may not add up due to rounding

Many applications are already emerging
New ones would need to grow as the economy decarbonizes

Bubble size in the legend corresponds to 1 million metric tons of hydrogen

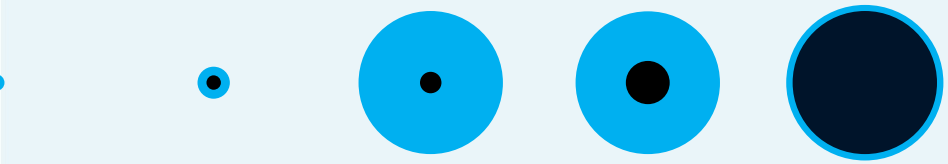
Potential hydrogen demand market size in 203

Potential hydrogen demand market size in 205

plished and emerging

Decarbonization short-term moves

Decarbonization long-term moves



buted wer

Forklifts/ material handling

Trucks:

Vans/LCV, medium- and heavy-duty trucks, captive trucks in ports and mines

Light-duty passenger vehicles:

All passenger cars including taxis, pickup trucks, SUVs, cross-overs

Existing feedstock

Steel

Virgin steel only

Aviation

Low-carbon fuels

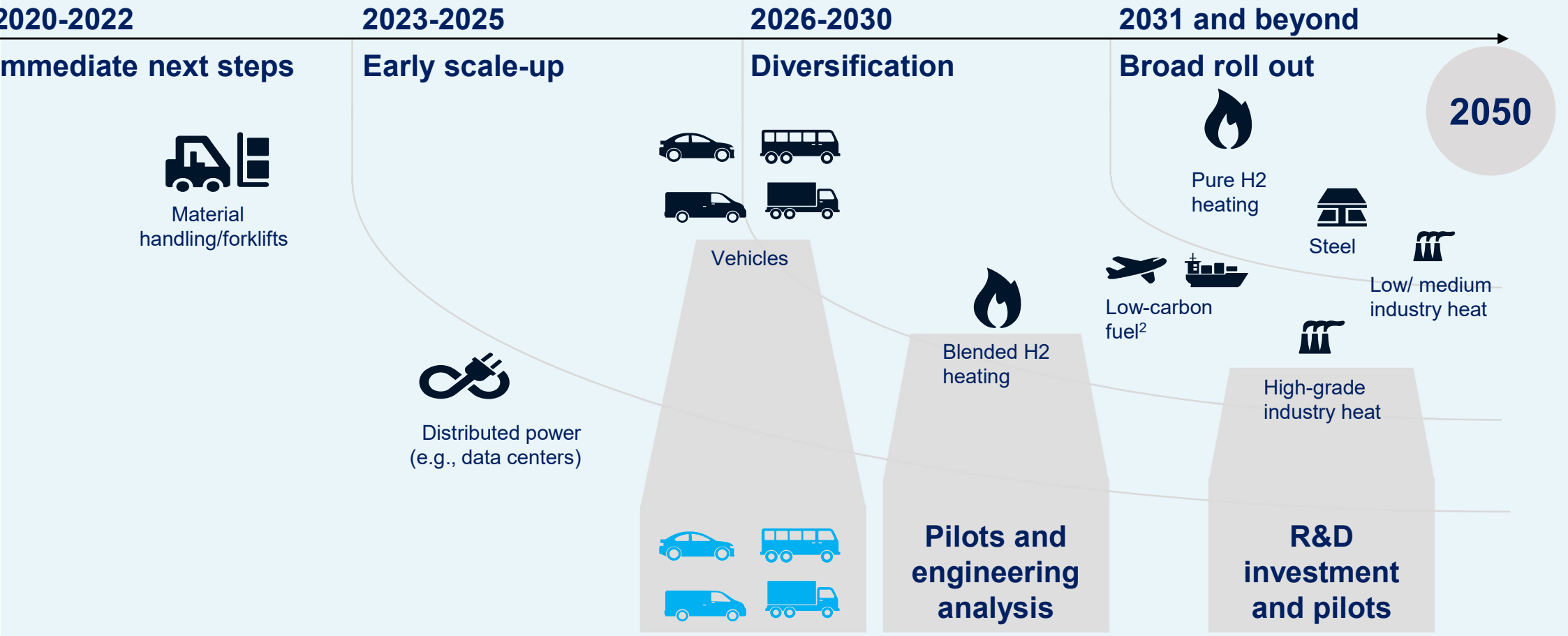
High-grade industrial heat

Residential and commercial buildings

Medium- and low-grade industrial heat

Central powe

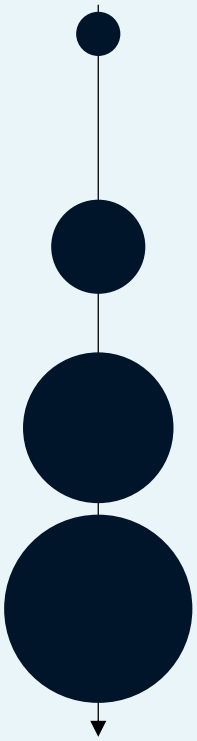
he roadmap describes 4 phases over the next decade to develop hydrogen across applications



U.S. H_2Road Map

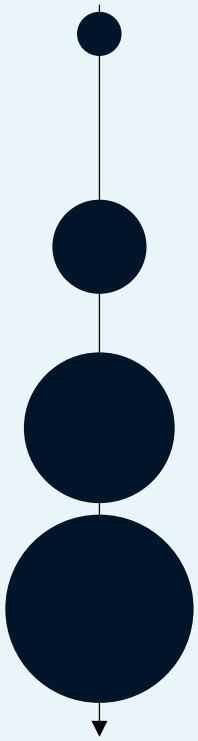
Scaling up Fuel Cell Vehicle Fleets and Hydrogen Fueling Stations

FCEV sales



Today	**2,500**	Immediate next steps
2022	**30,000**	Early scale-up
2025	**150,000**	Diversification
2030	**1,200,000**	Broad rollout

Fueling stations



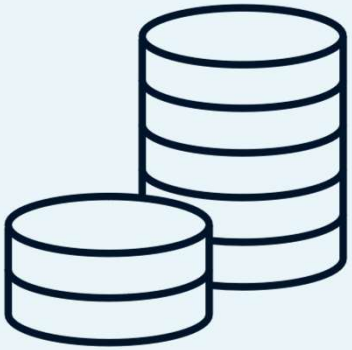
Today	**63**	Immediate next steps
2022	**165**[1]	Early scale-up
2025	**1,000**[1]	Diversification
2030	**4,300**[2]	Broad rollout

s of 500 kg/day; does not include material handling-fueling stations
of 1,000 kg/day; does not include material handling-fueling stations

U.S. H_2Road Map

Scaling up Economic Opportunities: Investments and Jobs

nnual investment



$1bn

2022

rly scale-up

$2bn

2025

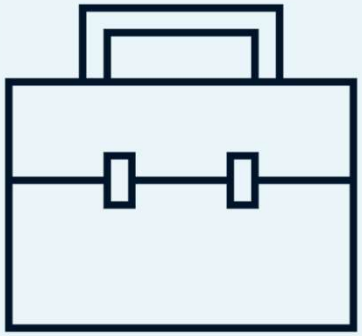
Diversification

$8bn

2030

Broad rollout

New jobs[1]



+50,000

2022

Early scale-up

+100,000

2025

Diversification

+500,000

2030

Broad rollout

udes direct, indirect, and resulting jobs

The US economy would benefit through emissions reduction, growth, jobs, & use of domestic energy resources

drogen in
e US could …

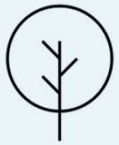
... Strengthen the US economy

~$750 bn
in revenue

3.4m
jobs

... Create a highly competitive source of domestically produced low-emission energy

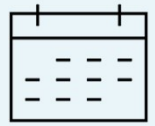
~100%
domestically produced



... Provide significant environmental benefits and improve air quality

-16%
CO_2

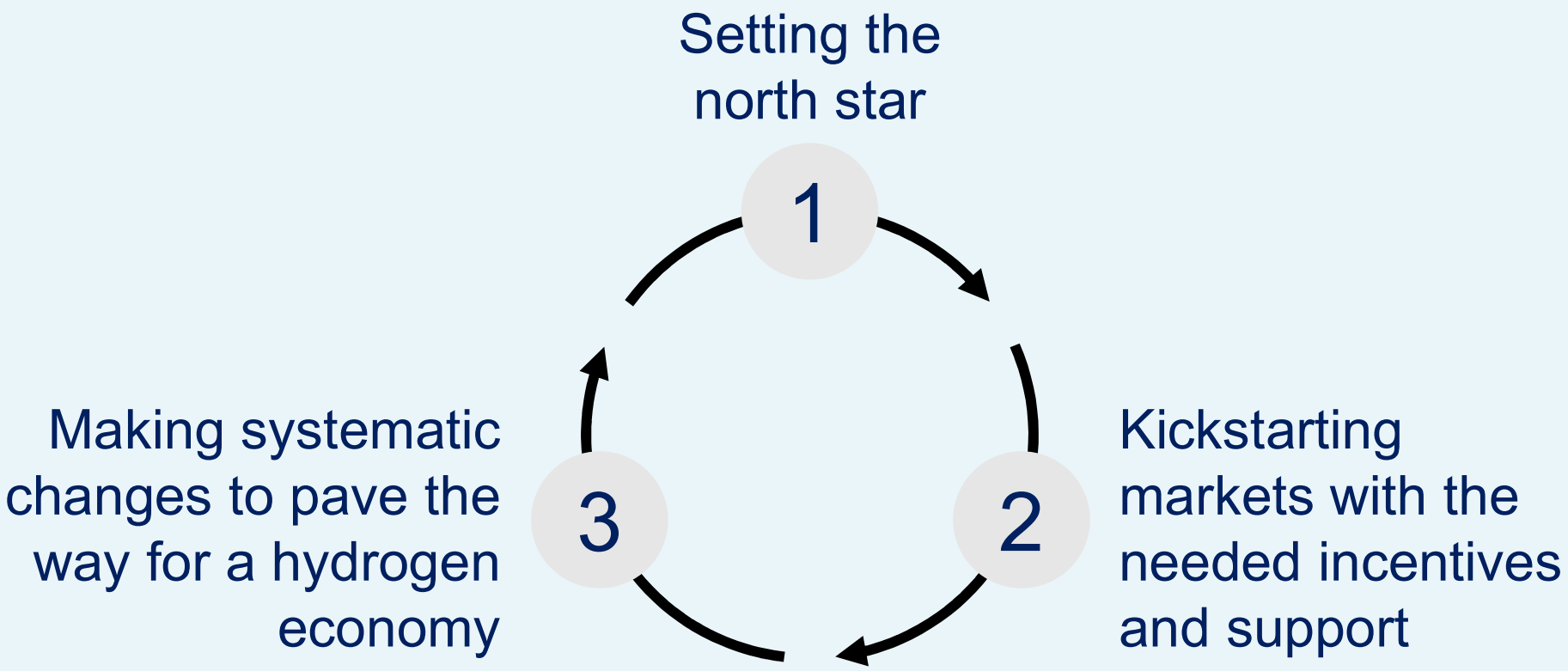
-36%
NOx



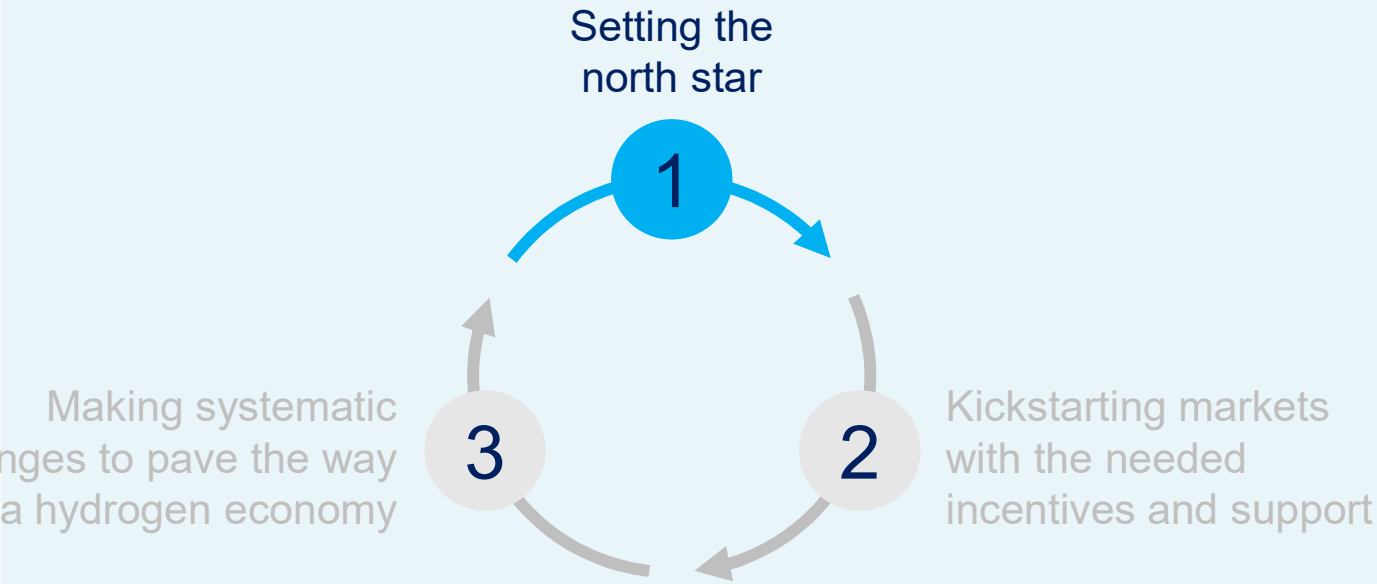
In 2050

nal energy demand excluding feedstock; share of abated CO^2 emissions relative to US emissions in 2050 as
ed in the IEA Reference Technology Scenario; for NOx, for tailpipe emissions only, based on EPA current NOx
ns

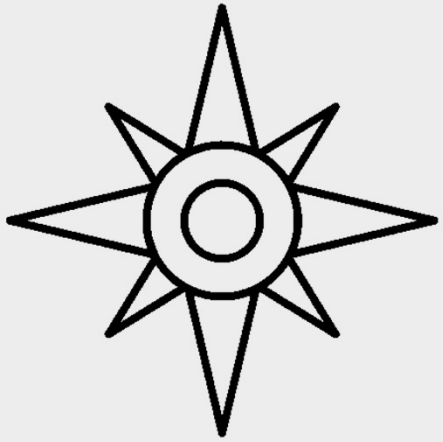
This road map is not on autopilot



Setting the North Star

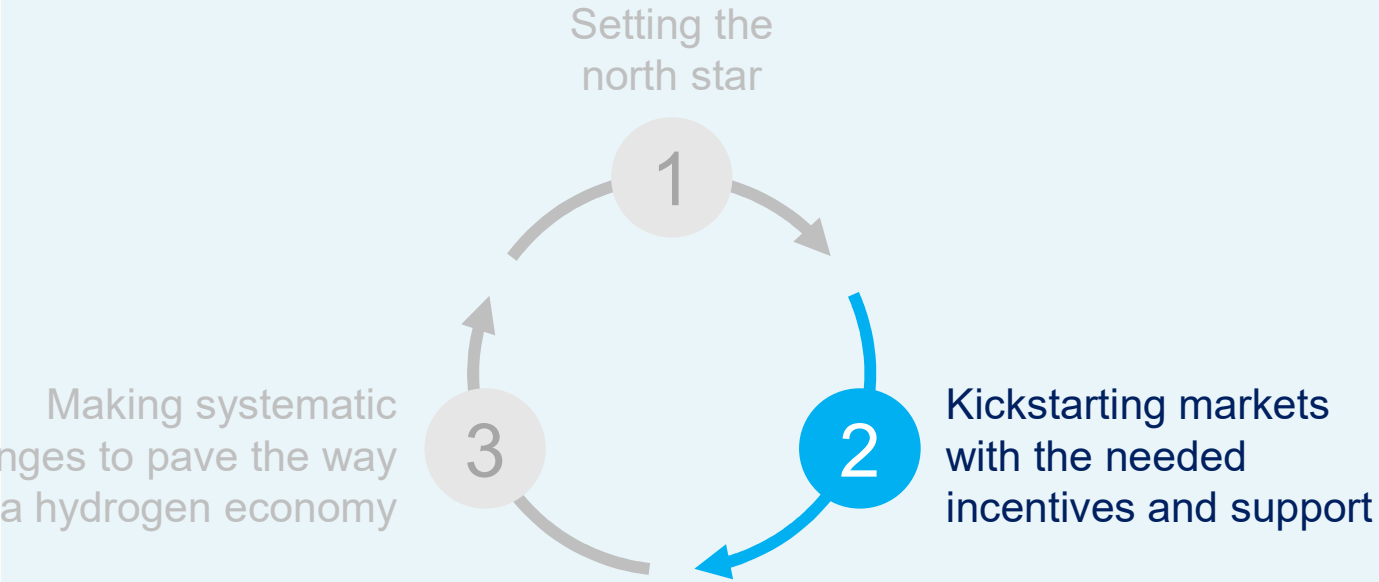


Key actions

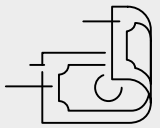


Set dependable, technology-neutral decarbonization goals

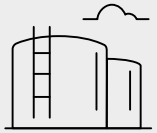
Kickstarting Markets



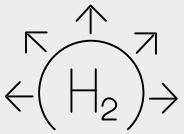
Key actions



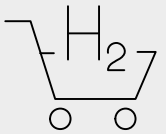
Create public incentives to bridge barriers to initial market launch



Support infrastructure development

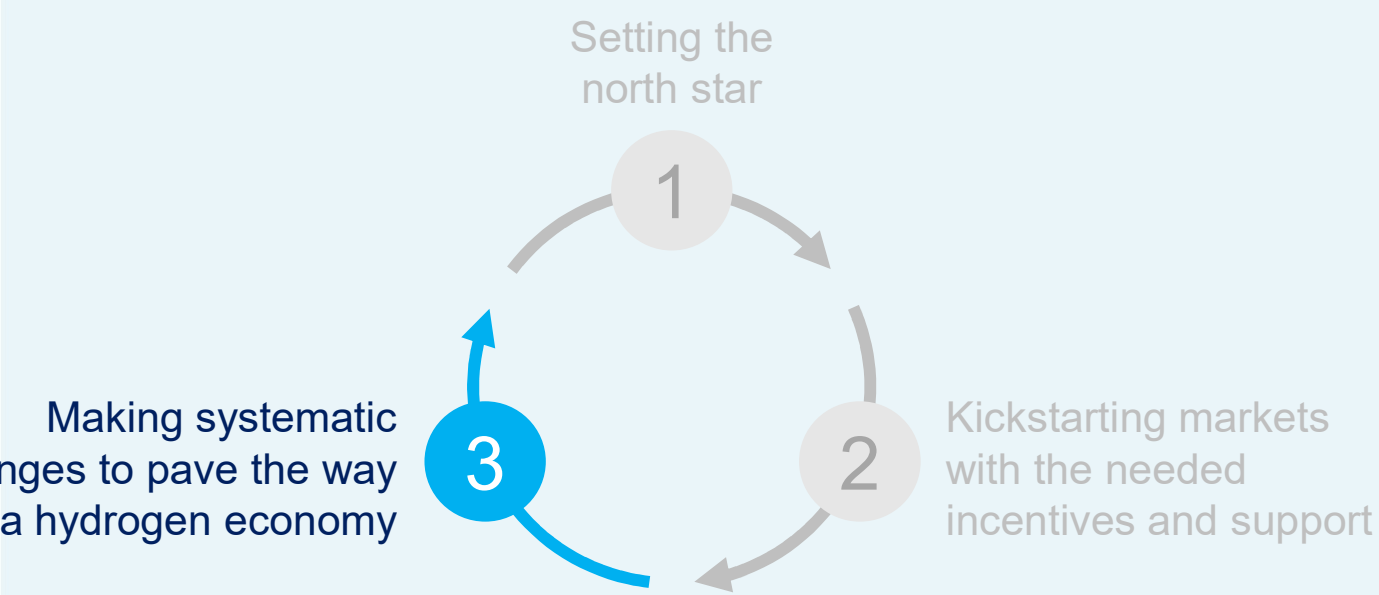


Expand the use of hydrogen across sectors and achieve economies of scale



Include hydroge based options i government procurement

Making Systemic Changes



Key actions

Support research, development, demonstration, and deployment

Harmonize tech codes and safe standards

Support outreach and workforce development

Review energy sector regulatio ensure they acc for hydrogen


Thank you.
uel Cell and Hydrogen Energy Association
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