RUN ON LESS

NACFE
NORTH AMERICAN COUNCIL FOR FREIGHT EFFICIENCY

Hydrogen as a Transportation Solution

Fleet Sustainability Technology

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North American Council for Freight Efficiency

- Unbiased, non-profit
- Mission to double freight efficiency
- All stakeholders
- Scale available technologies, guide future change and Run on Less demonstrations.
- Primary focus: Tractor-trailers

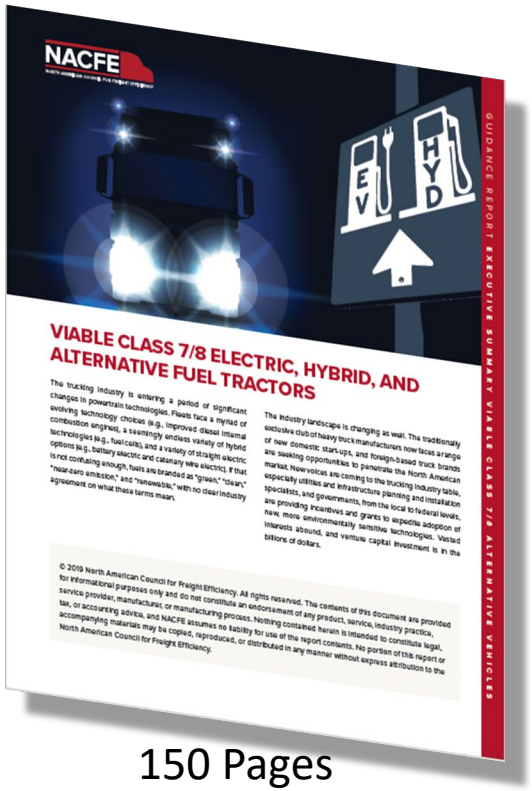
www.NACFE.org

10 YEARS NACFE
NORTH AMERICAN COUNCIL FOR FREIGHT EFFICIENCY

Guidance on Hydrogen

Making Sense of Heavy Duty Hydrogen Fuel Cell Tractors

143 Pages
235 References



150 Pages
222 References

Viable Class 7/8 Electric, Hybrid, and Alternative Fuel Tractors

https://www.nacfe.org

Many Bridges to the Future

PRESENT

Technology immature

Many unknowns & challenges

"MESSY MIDDLE"

Many optimized solutions

Growing infrastructure

Multi fuel choices

Innovation & maturation

Facts replace estimates

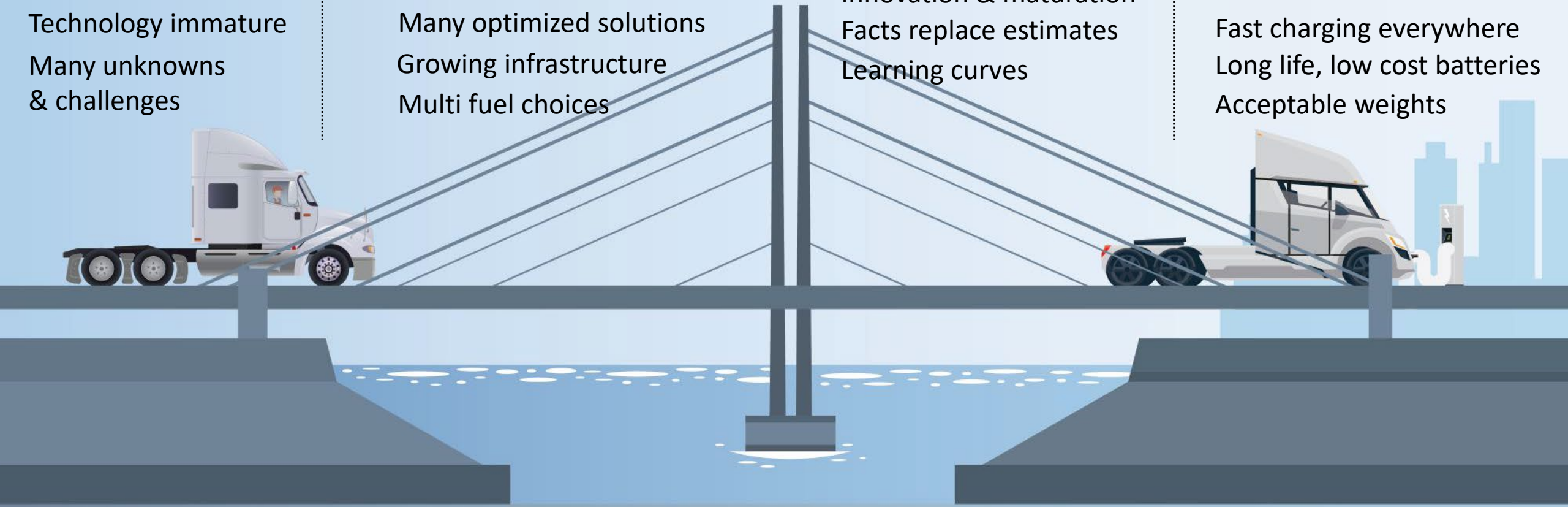
Learning curves

FUTURE 2050

Fast charging everywhere

Long life, low cost batteries

Acceptable weights



Legacy Diesels
Natural Gas

Diesel Advancements
Natural Gas
Hybrids

Battery Electric
Hydrogen Fuel Cells
Renewable Natural Gas & Diesel

CBEV & FCEV from Clean Energy

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The Hill Climb To Zero Emission

NA Trucks in Commercial Use

- 2.8M Tractors
- 8.8M Single Unit Trucks

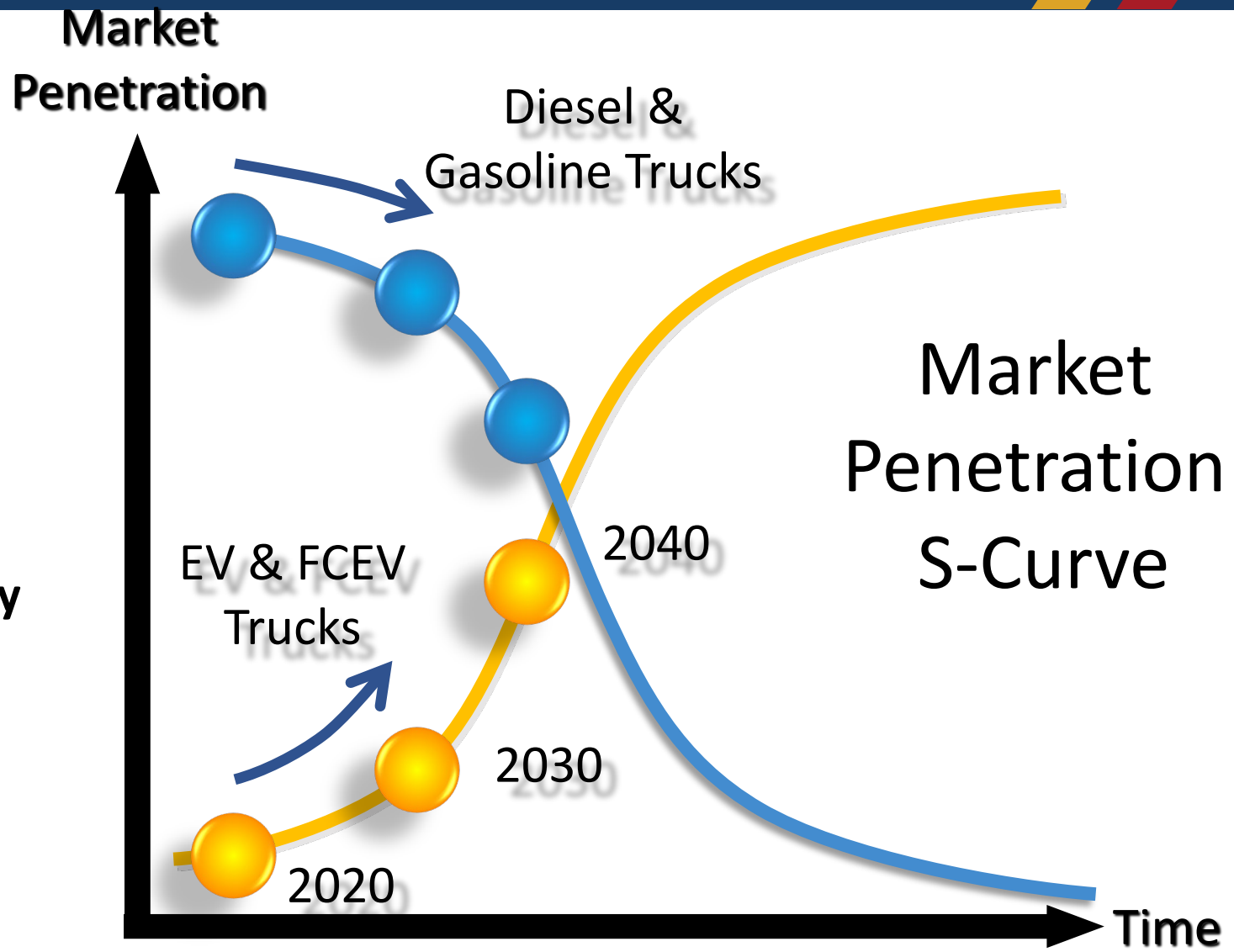
NA Annual Production Capacity

- ~320k HD Truck/Tractors
- ~350k MD Trucks

NA Production EV/FCEV Trucks Today

- < 100 HD
- < 5,000 MD

NA = North America



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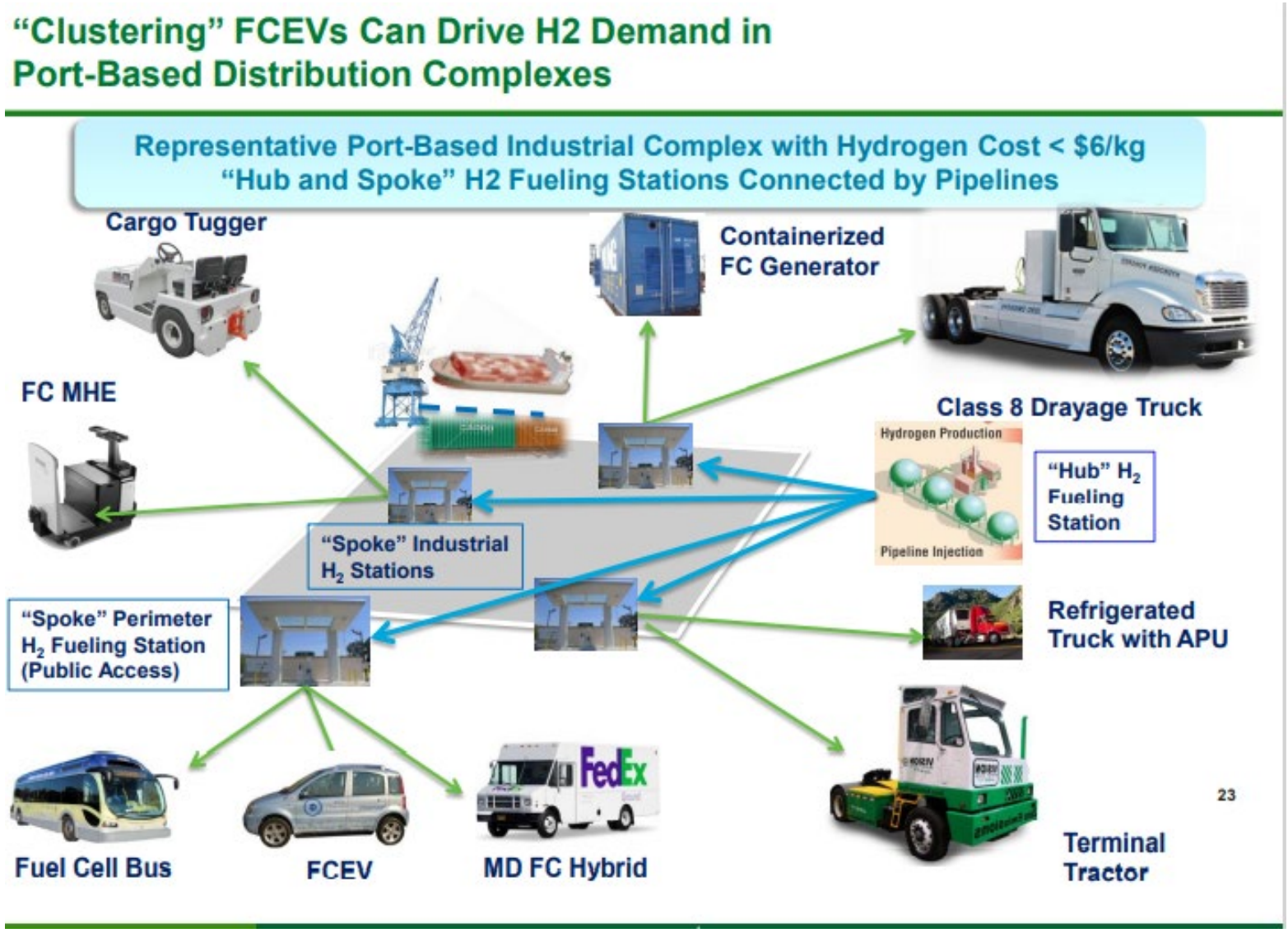
Hydrogen is Complicated

- A regional decision
- More than just trucking
- More than just debating efficiency
- More than debating fill times
- Its not H_2 vs EV
- Requires innovation
- Green hydrogen requires green electricity

Scaling is Regional

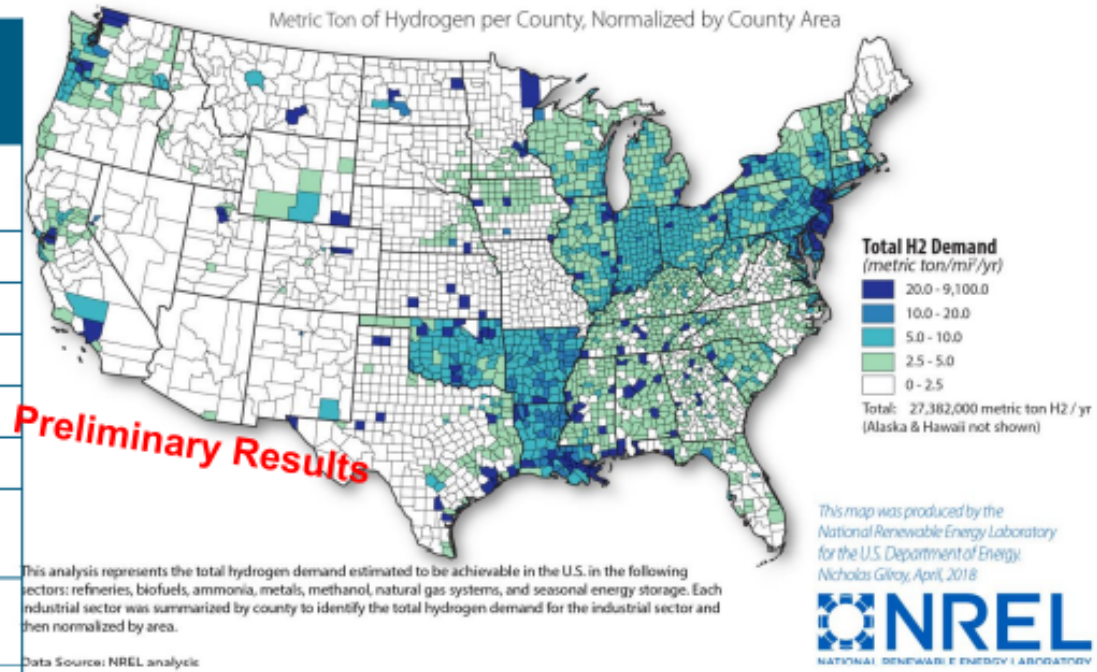


https://www.californiahydrogen.org/wp-content/uploads/2017/10/1620-Devlin-DOE.pdf

Scaling is not just Trucks

H2@Scale Analysis: Estimated Technical Potential Hydrogen Demand

Demand	Technical potential (MMT* / year)
Refineries & CPI§	8
Metals	6
Ammonia	5
Methanol	1
Biofuels	1
Natural Gas	7
Light Duty Vehicles	28
Other Transport	3
Electricity Storage	28
Total	87



This analysis represents the total hydrogen demand estimated to be achievable in the U.S. in the following sectors: refineries, biofuels, ammonia, metals, methanol, natural gas systems, and seasonal energy storage. Each industrial sector was summarized by county to identify the total hydrogen demand for the industrial sector and then normalized by area.

Data Source: NREL analysis

Technical Potential Demand: 87 MMT/yr

Current U.S. market: ≈ 13 MMT/yr

Including captive generation for ammonia and refining

* MMT: Million metric tonnes

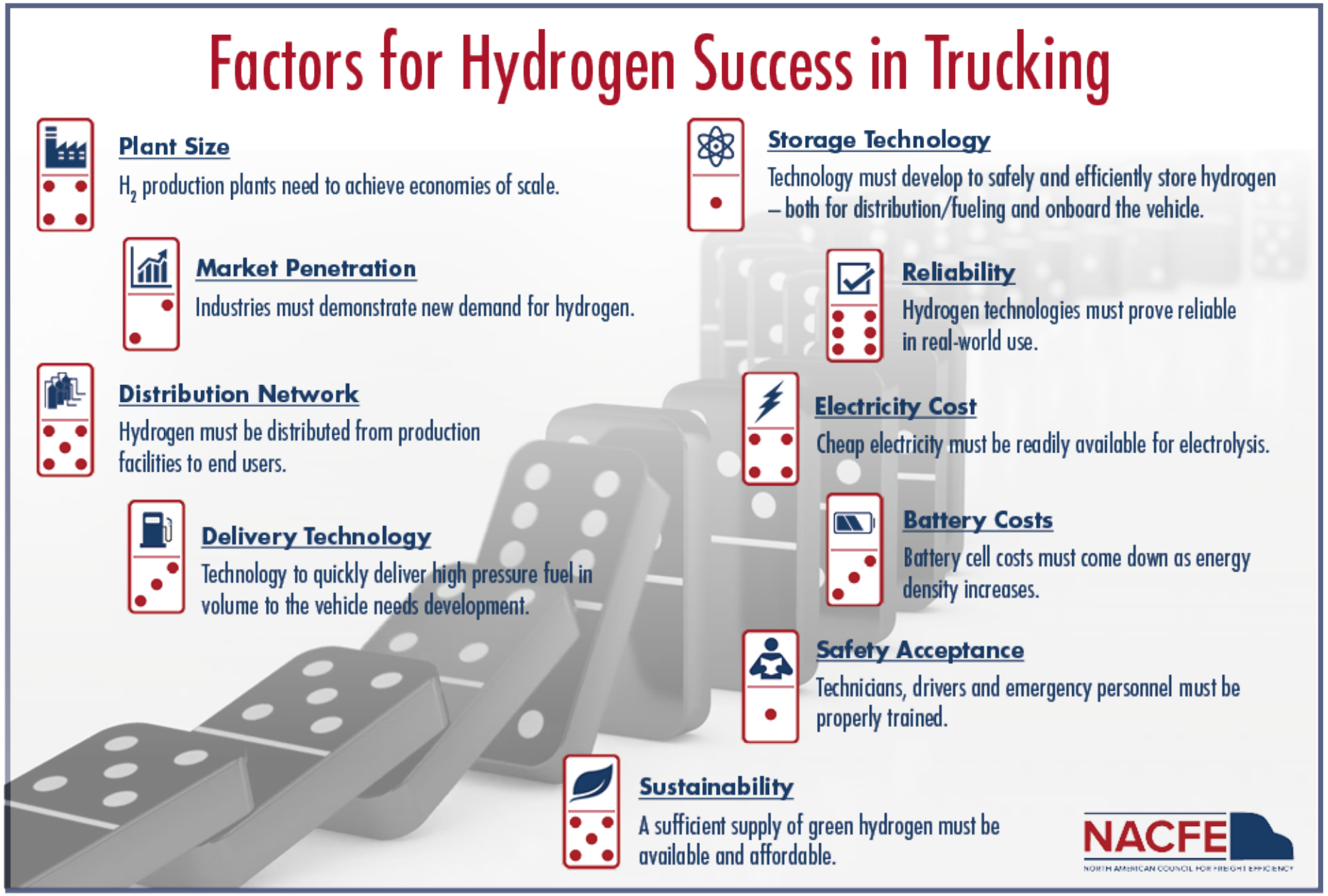
§ CPI: Chemical Processing Industry not including metals, ammonia, methanol, or biofuels

Light duty vehicle calculation basis: 190,000,000 light-duty FCEVs from http://www.nap.edu/catalog/18264/transitions-to-alternative-vehicles-and-fuels

U.S. DEPARTMENT OF ENERGY | OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY | FUEL CELL TECHNOLOGIES OFFICE | 20

https://www.californiahydrogen.org/wp-content/uploads/2017/10/1620-Devlin-DOE.pdf

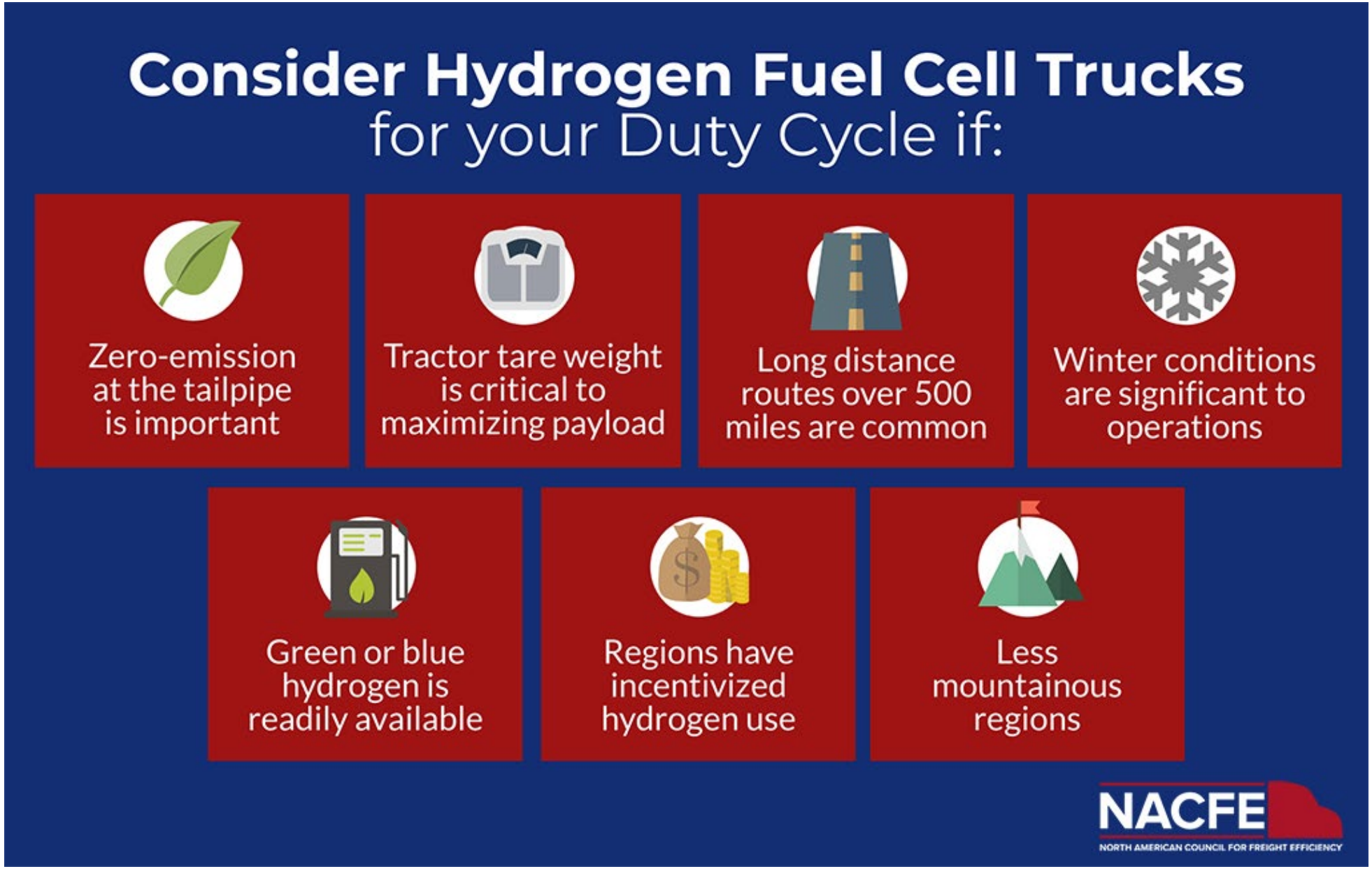
Hydrogen Success Factors



Hydrogen Fuel Cell Trucks

- Several in fleet test
- OEM development
- Production plans
- Compressed & Liquid Hydrogen

Hydrogen Opportunities



Hydrogen Fuel Cell Conclusions

- Hydrogen fuel cell trucks are just starting to see real-world use and their adoption is being driven by regional or national considerations that are much bigger than what exists for trucking fleets.
- Battery electric trucks should be the baseline for hydrogen fuel cell electric vehicle (HFCEV) comparisons, rather than any internal combustion engine alternative.
- As for all alternatives, fleets should optimize the specifications of FCEVs for the job they should perform while expecting that the trade cycles will lengthen.
- The future acceleration of FCEVs is likely not about the vehicles or the fueling but more about the creation and distribution of the hydrogen itself.
- Finally, the potential for autonomous fuel cell trucks to operate 24 hours a day adds significant opportunity for making sense of capital and operational investment in hydrogen.

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THANK YOU

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