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Sustainable Fleet Technology Conference 2023

Advancements in Medium/Heavy Duty Vehicles and Infrastructure

The need to pursue all pathways for transport decarbonization

Dr. Ameya Joshi

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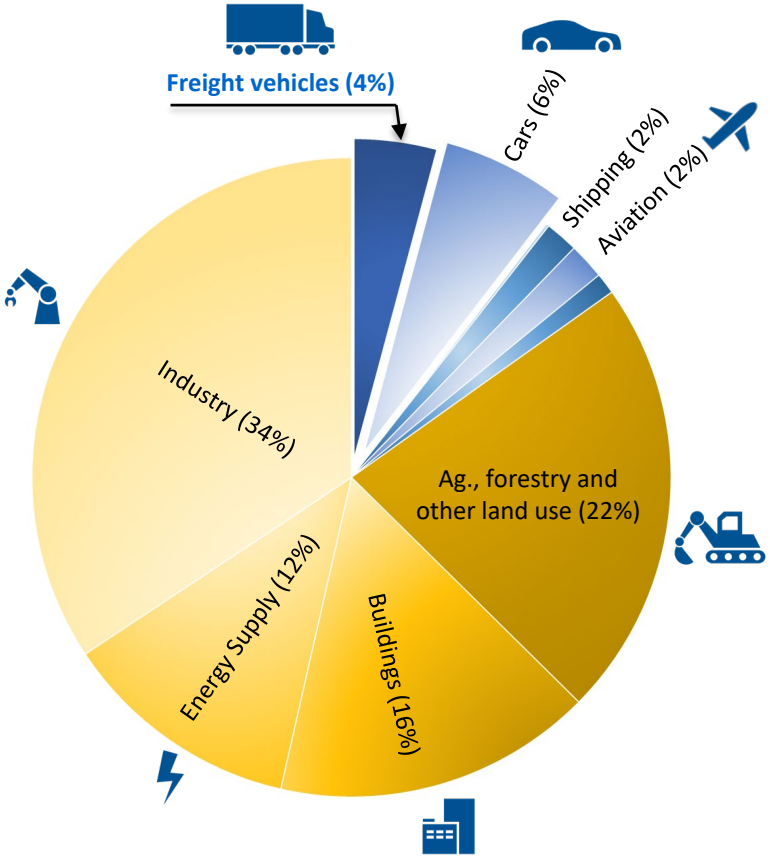
joshia@corning.com

https://www.linkedin.com/in/joshiav/

What problems are we are trying to solve in the transportation sector?

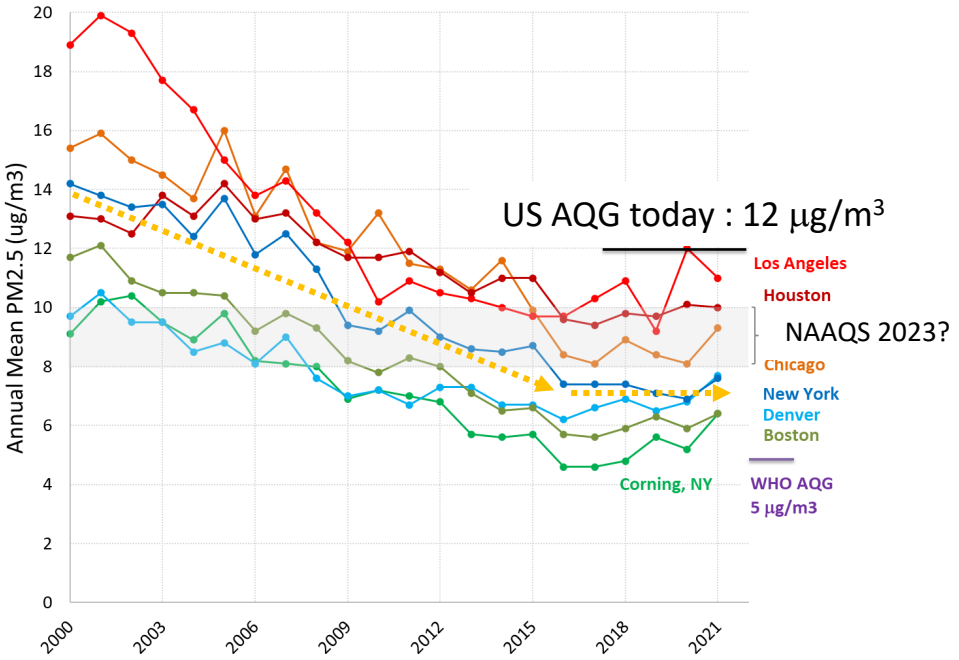
Global Greenhouse Gas emissions



Source: IPCC 2022 https://www.ipcc.ch/report/ar6/wg3/

Local Criteria Pollutants

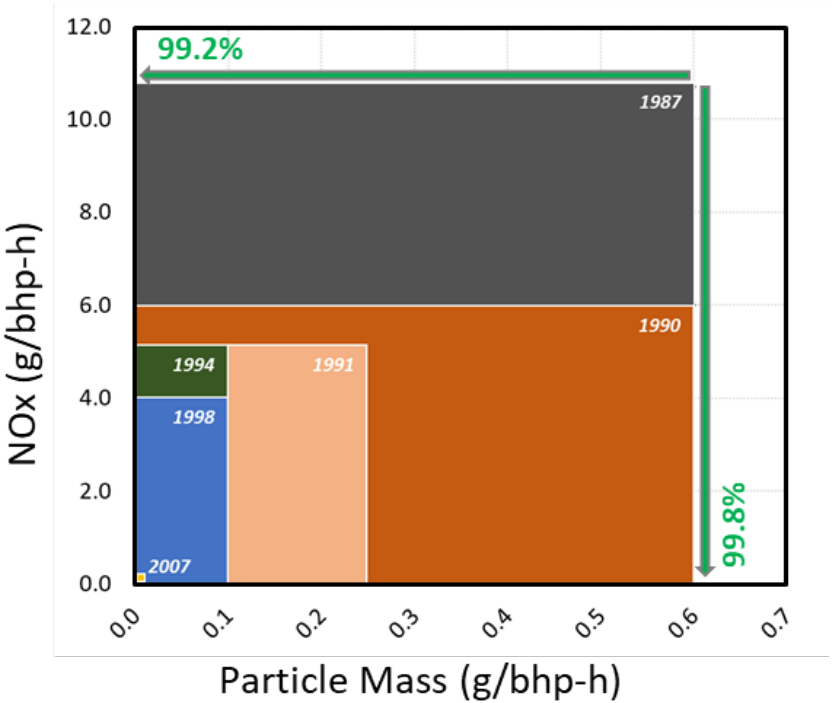
We are nearing zero-impact emissions with upcoming regulatory steps (~ Euro 7/VII/EPA Tier 4/Low NOx/CN 7 …)

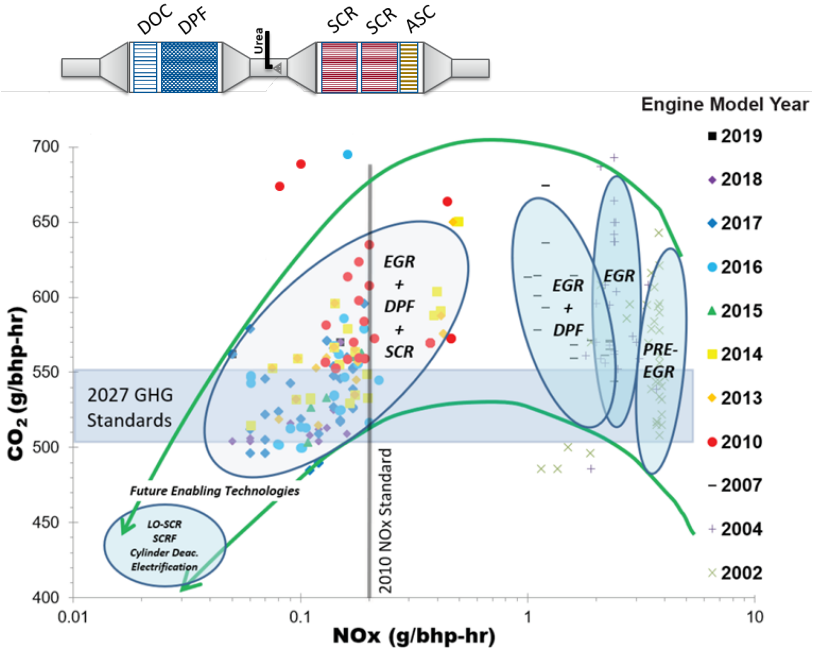


Source: https://www.epa.gov/air-trends/air-quality-cities-and-counties

In the past 35 years, tailpipe criteria pollutants have reduced by >99% … while also reducing fuel consumption

US EPA heavy-duty diesel tailpipe standards





DOC = Diesel Oxidation Catalyst, DPF = Diesel Particulate Filter
SCR = Selective Catalytic Reduction (of NOx), ASC = Ammonia slip catalyst
EGR = Exhaust gas recirculation

Heavy duty engines serve diverse vehicle applications
- Decarbonization will require a range of technology solutions

Total in-use ~ 23 million

% GHG	% NOx	% Fleet
48%	47%	9%
		5%
		34%
12%	13%	1%
		2%
22%	20%	49%
2%	3%	
1%	1%	
16%	17%	

Long haul tractor ~ 300 - 500 mi

Regional haul tractor
~ 150 – 300 mi

Vocational ~ 50 – 150 mi

Transit bus ~ 150 mi

School bus ~ 100 mi

HD pickup / van ~ 50 – 75 mi

Vehicle Class

- Class 7 - 8
- Class 3 - 7
- Class 7 - 8
- Class 2b - 3

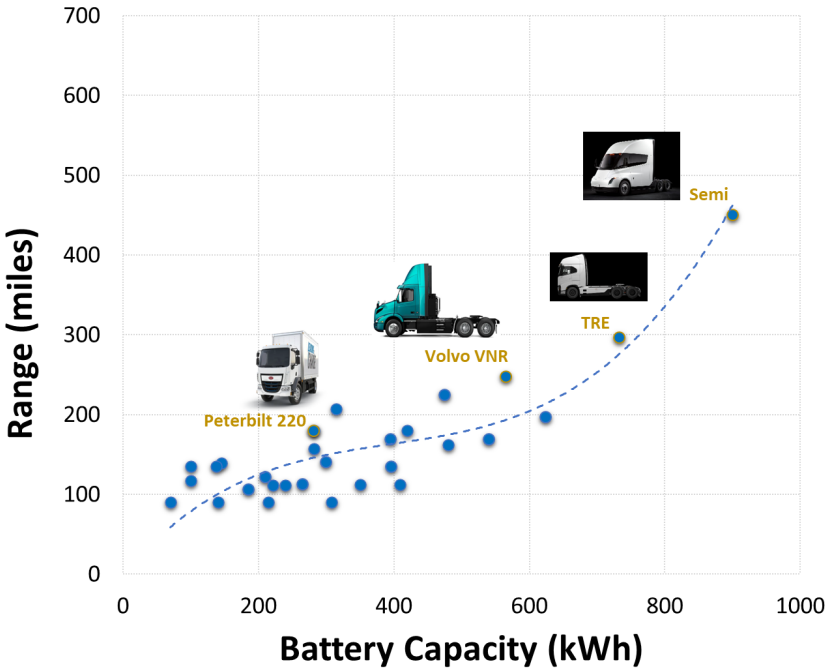
Fuel type

Diesel
Gas
Other

Long-haul trucking : Need to advance megawatt charging & H_2 delivery

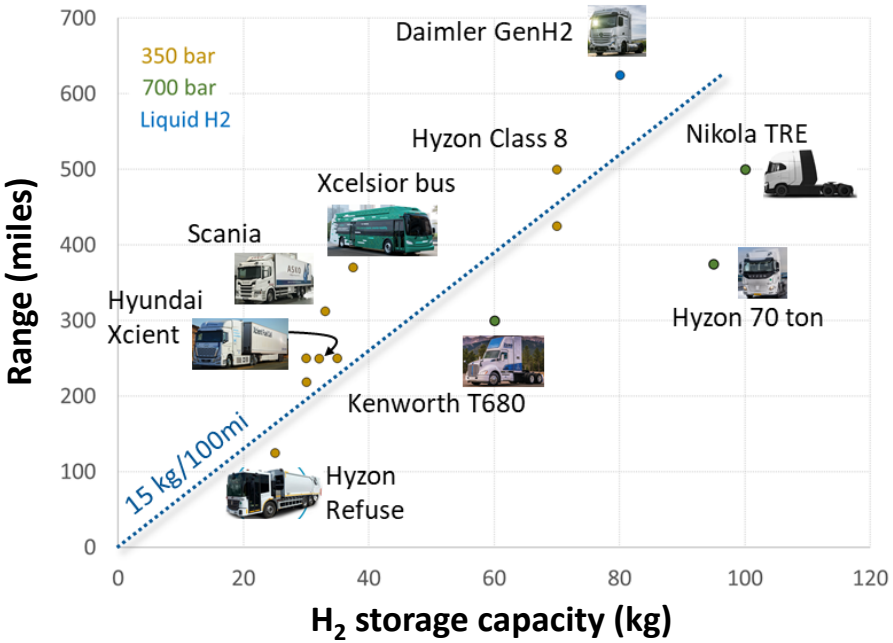
Battery Electric Trucks

~ 1MWh battery pack needed for 500+ mile range



H_2 fuel cell trucks

Need to significantly increase green H_2 production



For ~ 0.5M long-haul trucks running 350 mi per day, H_2 annual requirement = ~ 9.6M tons

US total H_2 demand today is 10M tons per year, almost all made from fossil fuels

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Several technology choices to reduce well-to-wheel CO_2 emissions - Each with their pros and cons

	IC Engine (Ref.)	Low C Fuels	BEV	H_2 Fuel Cell	H_2 ICE
GHG Reduction	Ref.	++	+++	++	+
Fueling Infrastructure	Ref.	o (Ready)	--	---	---
Refueling Time	Ref.	o	--	o	o
Range	Ref.	o	--	o	o
NOx/PM emissions	Ref.	o	+++	+++	+
TCO	Ref.	---	++/-- (*)	++/-- (*)	--
Critical materials	Cat. only	-	-	-	o
Existing fleet	Ref.	Yes	No	No	No

(*) Depends on application and various assumptions

We need to pursue all pathways for transport decarbonization

Detroit DD15, inline 6-cyl
2024 GHG compliant

Efficiency improvements
55% BTE, Opposed piston

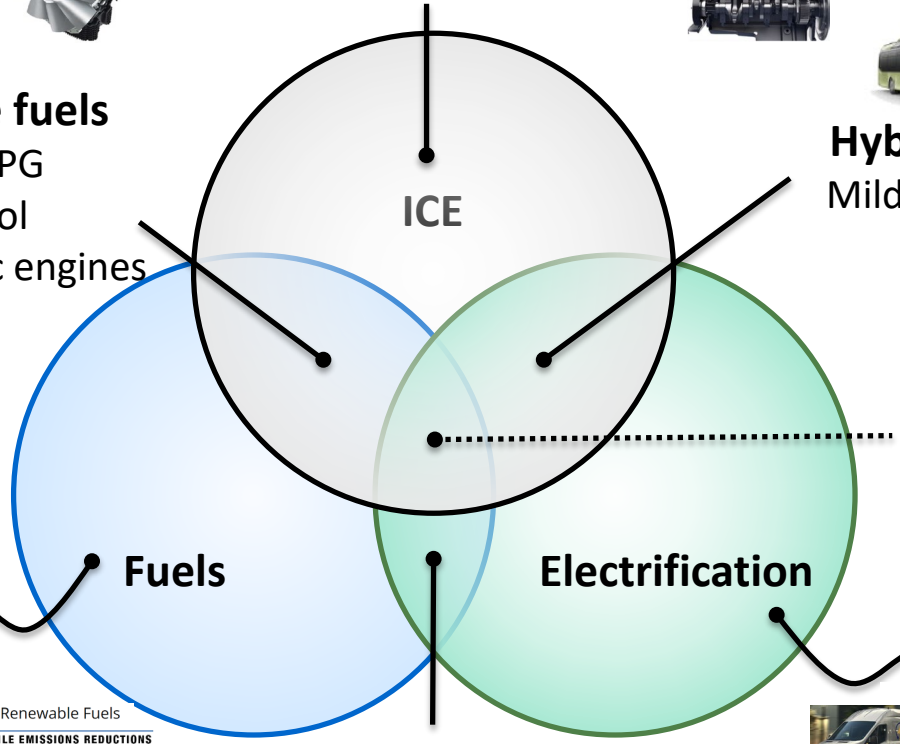
AchatesPower Opposed
Piston engine

Volvo 7900 hybrid

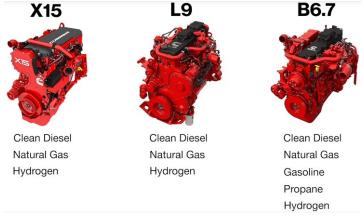
ClearFlame Engine
Runs on ethanol

Alternate fuels
CNG, LPG
Ethanol
Fuel agnostic engines

Hybridization
Mild, full hybrid



Cummins
fuel agnostic
engines



Hybrid + green fuel
H_2 ICE
Plug-in + Syn fuel

Cummins
15L H_2 ICE

Low carbon fuels
Renewable fuels

Phillips 66 Makes Final Investment Decision to Convert San Francisco Refinery to a Renewable Fuels Facility

May 11, 2022

It will be one of the world's largest facilities of its kind; expected to begin commercial operation

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MOBILE EMISSIONS REDUCTIONS

↓ 8 million
metric tons per year of lifecycle carbon emissions reductions, the equivalent of taking 1.4 million cars off the road

Synthetic fuels
e-diesel

ZEVs
Battery electrics
Fuel cell vehicles

Thank you !

Contact Info

joshia@corning.com

https://www.linkedin.com/in/joshiav/