NZ CLEAN HIGH DUTY CYCLE[1] TRANSPORT: RESEARCH CHALLENGES

	Land		Marine		Aviation			Indicative Challenges[2]		
	Road	Rail	Short e.g. Waiheke	Coastal +	Short e.g. drones	Regional	Long-haul			
Supply - Fuel								**Fuel production**	**Storage/ distribution**	**End use**
Fossil fuels + CCS → Hydrogen (H_2)[3] → Fuel Cell (FC)	?✓?	?✓?	✓✓?		✓✓?			Conversion mature and sets the benchmark for potential alternative fuels. CCS not mature.	H_2 energy density & containment. H_2 carriers are address H_2's weaknesses, but not mature.	FC cost, efficiency and scale up of production still issues.
Power → H_2 → FC	?✓x	✓✓x	✓✓x		✓✓?			Conversion mature, but cost and efficiency issues remain.	As for fossil fuel H_2. [But distributed production an option].	As for fossil fuel H_2.
Power → Electric Vehicles (EV) + enhanced charging (incl. gantries etc)	✓✓?	✓✓✓						Mature	Battery energy density and specific energy, charging technology & speed. Distribution of power mature.	Mature. The addressable market will be defined by the economics of the enhanced charging system.
Biomass → Biogas (e.g. biomethane)[4]	x✓✓	?✓✓	✓✓✓		✓✓?			Feedstock availability (e.g. waste), dispersed resource, cost and efficiency of pre-processing and upgrading (but both mature).	Mature. Liquid fuels likely to be preferred in the long haul marine and aviation applications.	Biomethane in an Internal Combustion Engine (ICE) mature. Challenges in other gas/motor combinations.
Biomass → Liquid Biofuel	✓✓✓	✓✓✓	✓✓✓	✓✓✓	✓✓?	✓✓x	✓✓x	Land use, dispersed resource, cost etc. of pre-processing and upgrading (latter not yet mature).	Mature	Mature depending on level of upgrading and nature of motor. Drop-in possible for ICEs.
Power & Biofuels → EV & ICE hybrid	✓✓?	✓✓?	✓✓?	✓✓✓	✓✓?	✓✓?		Power mature. Biofuel production as above, lower volumes needed.	Addresses battery energy density and specific energy in EVs	Cost of two technologies. Power density in aviation conversions.
Power & H_2 → EV & FC hybrid	✓✓?	✓✓?	✓✓?					Power mature. H_2 production as above, high cost has less impact.	H_2 as above but less acute	As above for Bio → Hybrid use.
Demand reduction										
Logistics	-✓✓	-✓✓		-✓✓	-✓✓	-✓✓	-✓✓	"Last mile", impact of ICT/AI/embedded intelligence, modal mix and vehicle efficiency, better sharing		
Telepresence etc	-✓✓	-✓✓				-✓✓	-✓✓	Human acceptability, technologies and local infrastructure, 3D printing		

Ticks etc. are a very initial and subjective assessment of respectively: feedstock availability relative to market; technology maturity by 2030; and approximate 2030 NZ price relative to a baseline of fossil fuel + CO_2-e @ $100/t. For demand reduction "feedstock" is not applicable. All fuels can achieve some degree of technology maturity at scale by 2030, the challenge is to then reduce the price, although markets will buy on more than price alone. Power → EV will be economic at the margin of many of the markets, defining the low duty cycle boundary, and is not shown.

Main sources: "Hydrogen in NZ" (2019) Concept Consulting; "NZ Biofuels Roadmap" (2018) Scion.

[1] Limited to high duty cycle assuming battery technology will be used in applications not constrained by storage and recharge time limitations.
[2] A very high-level initial identification of where the research challenges lie
[3] Including various potential hydrogen carriers such as ammonia and synthetic fuels e.g. methanol.
[4] Biomass → Bio H_2 is an option but is less mature than (say) biomethane production; storage and distribution is more complex; and end use isn't a retrofit of existing engines.