Achieving a Timely, Efficient, Equitable and Orderly Transition to Net-Zero Emissions in Transport

Webinar for the Transport Knowledge Hub, and Ministry of Business, Innovation and Employment

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Outline

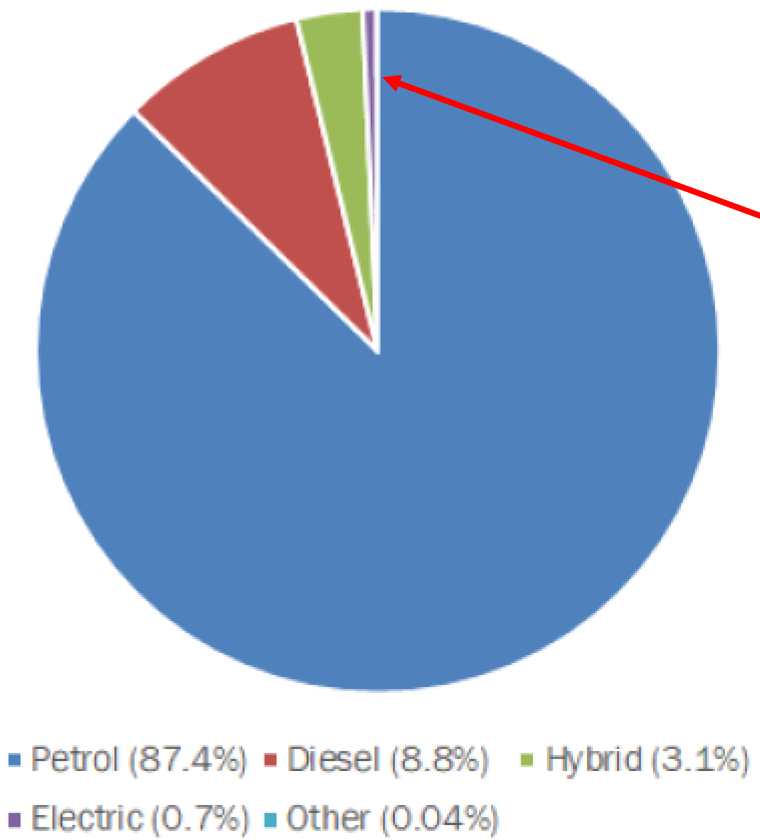
1. Introduction
2. Framing the key challenges
3. Lessons from past transport revolutions
4. New Zealand's transition preconditions, and policy questions and levers
5. Take-home messages

Introduction

- This is a high-level summary of a research-based, policy-oriented report completed for Vector, Powerco and First Gas:
  - The report represents my views, not these sponsors' – Vector and Powerco are primarily electricity distributors, while First Gas is exclusively in gas, so their interests are diverse.
- The report's main focus, like this presentation's, is on passenger transport – starting with the challenges, and then outlining some possible solutions.
- The report is **technology agnostic** vis-à-vis battery electric vehicles, hydrogen, e-fuels, etc – discussing pros/cons of each:
  - It is a general discussion document of how "best" to achieve the transition to net-zero by 2050 – i.e. *in a timely, efficient, equitable and orderly way*.

A Glimpse of the Challenge

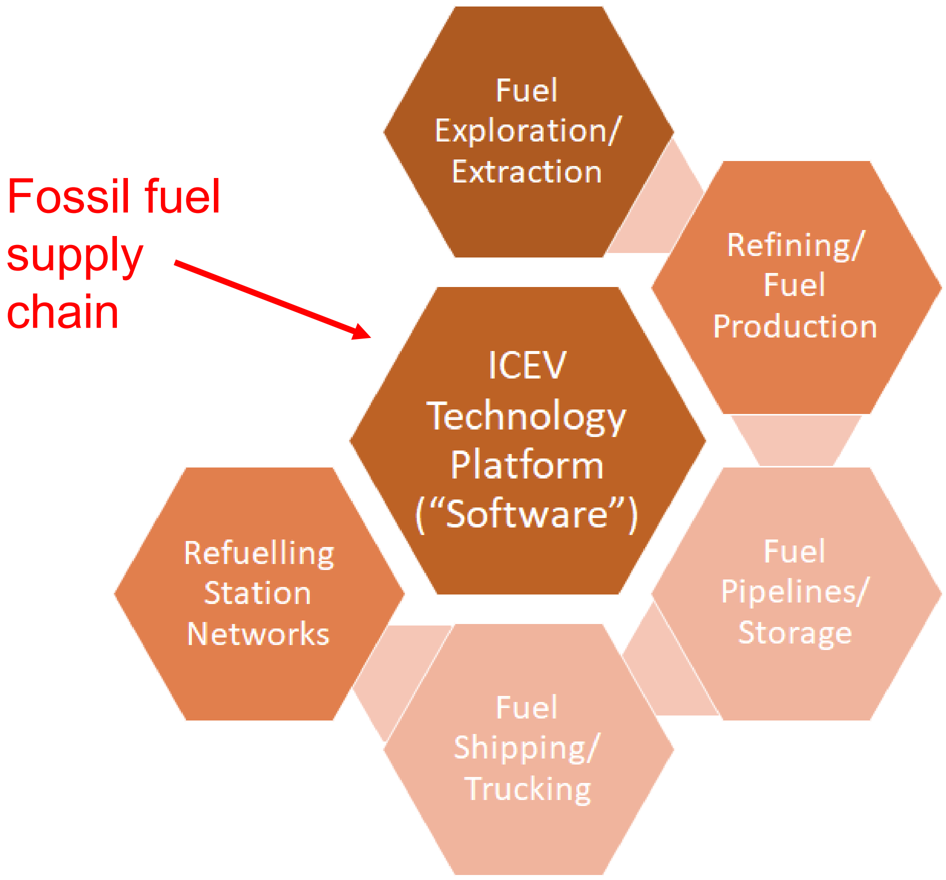
Figure 1.1 – Composition of New Zealand's Fleet of Passenger Cars and Vans, September 2021



In September 2021 less than 1% of New Zealand's 3.5 million passenger vehicles were electric:
→ Starting the net-zero transition practically from "zero" (not in the good sense)!

Source: based on data from New Zealand Transport Agency.[2]

Diving Deeper – Transitioning to Net-Zero is all about Competition between “Platforms” …

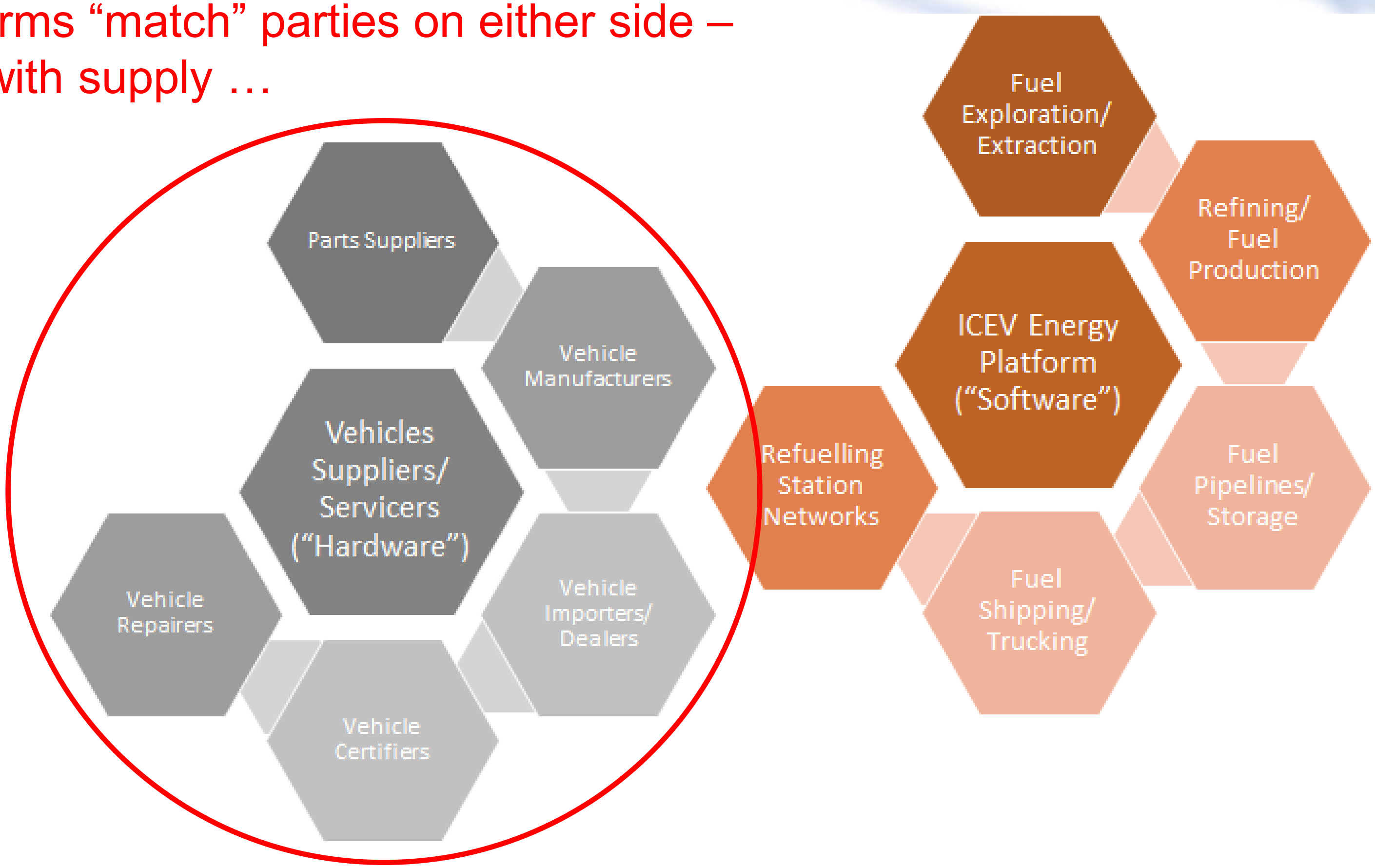


The fossil fuel supply chain is a deeply-entrenched (i.e. has an <u>enormous incumbency advantage)</u> energy platform for ICEVs:

- Developed over a century, with huge sums already invested;
- Capacity optimised to sustain current transport requirements;
- Might be converted to clean fuels more cheaply than building new supply chains …

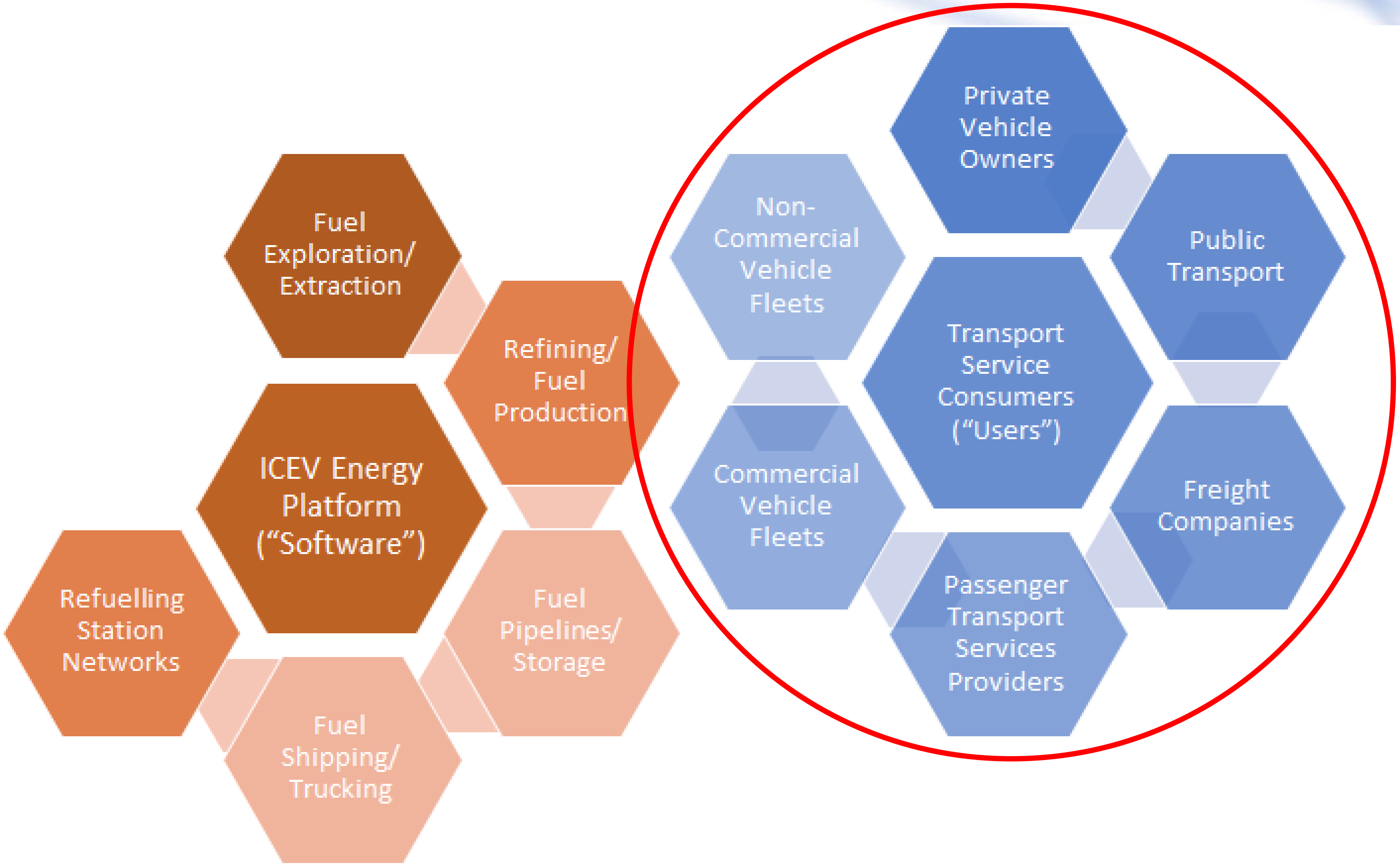
ICEV Energy Platform (cont'd) – Supply Side

Platforms "match" parties on either side – start with supply …



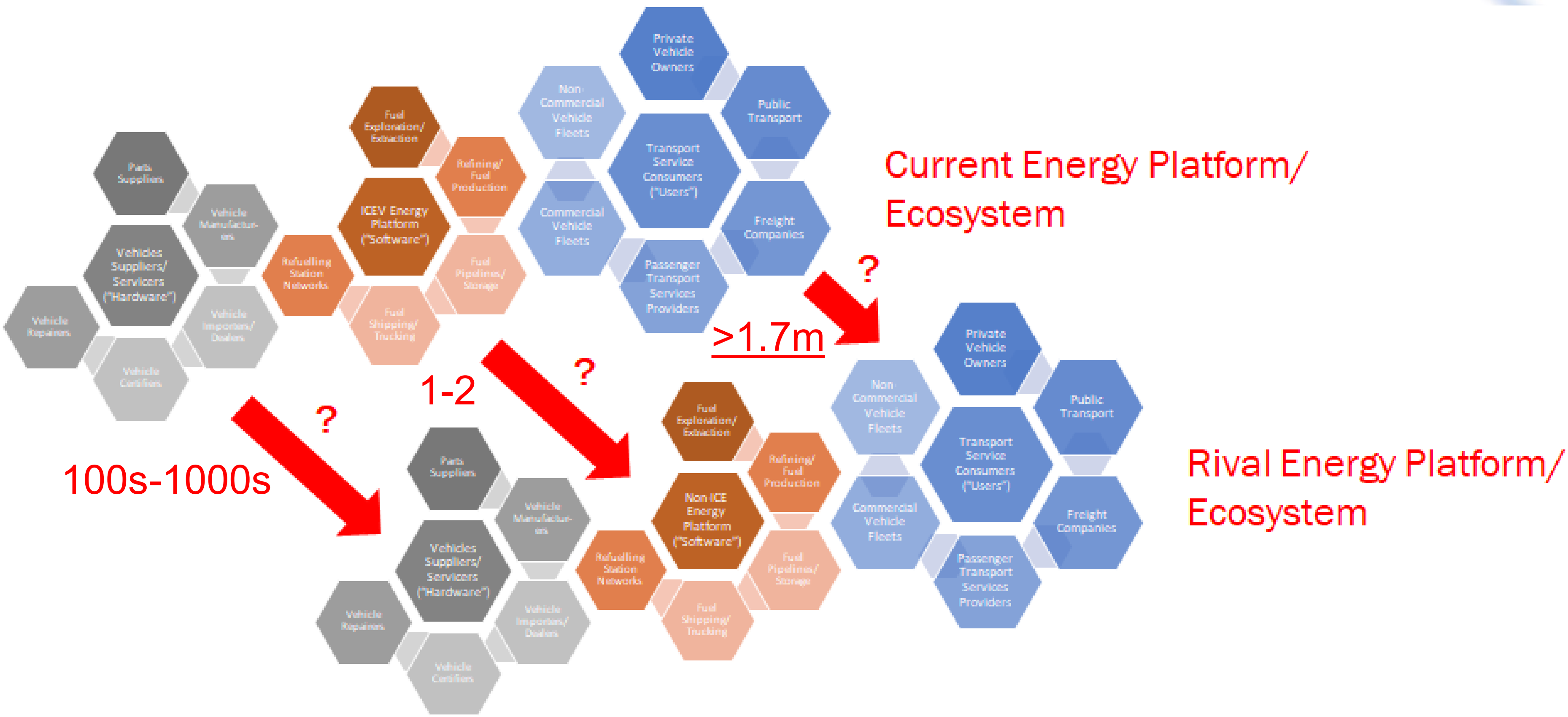
This side of the fossil fuel platform/ecosystem also has an enormous incumbency advantage – e.g. ICEV cost and performance is the "default"

ICEV Energy Platform (cont'd) – Demand Side

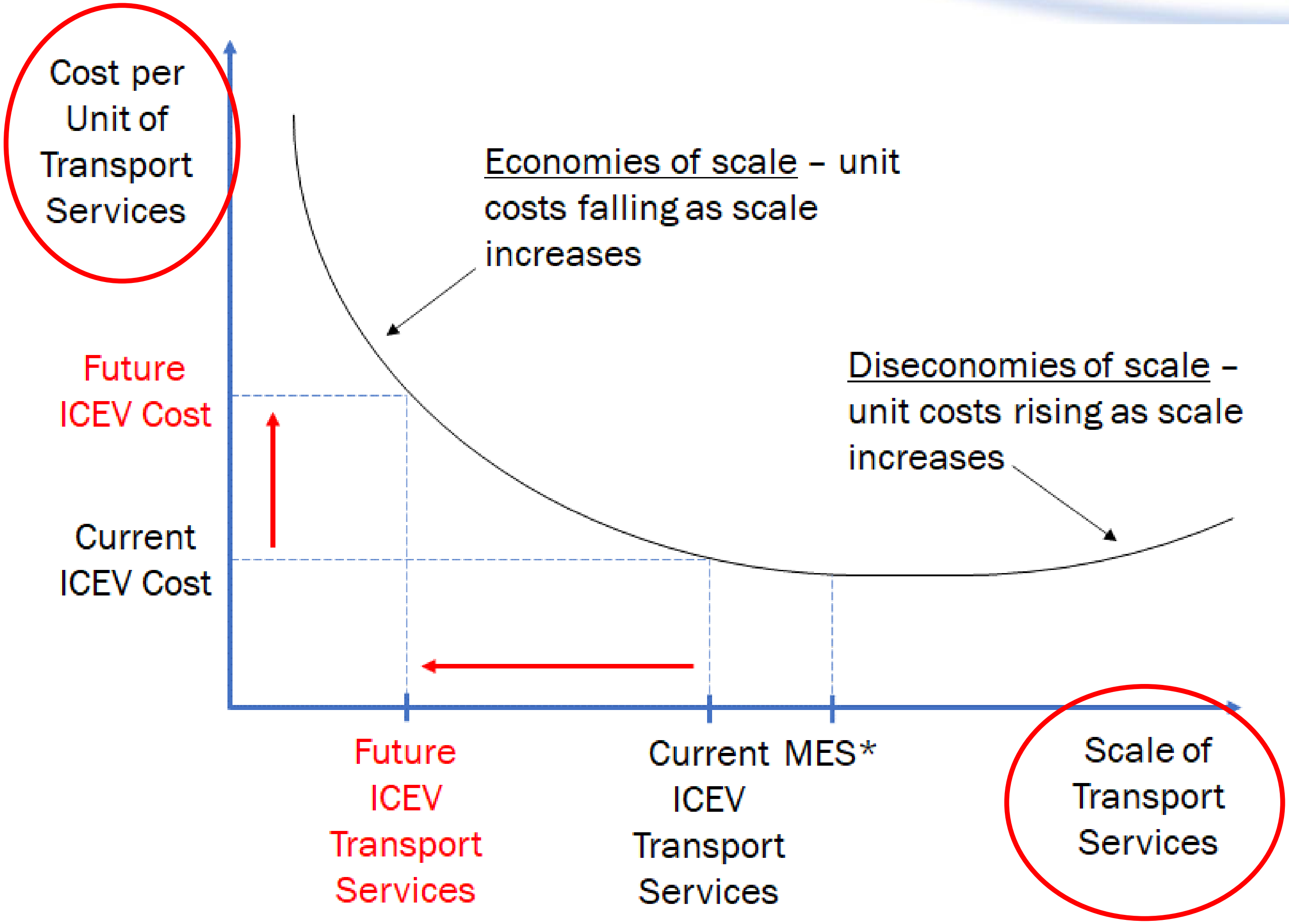


The demand side of the platform will have considerable inertia, reflecting not just past vehicle investments, but even more ingrained choices about where we live/work/play/shop, and how we travel and move stuff.

Key Challenge 1 – Transitioning to Net-Zero means Migrating 1.7m Households (Etc) and Hardware Suppliers/Servicers to a Clean Energy Platform (Which Doesn't Yet Fully Exist)



Key Challenge 2a – Platforms feature **Scale Economies** and Network Effects

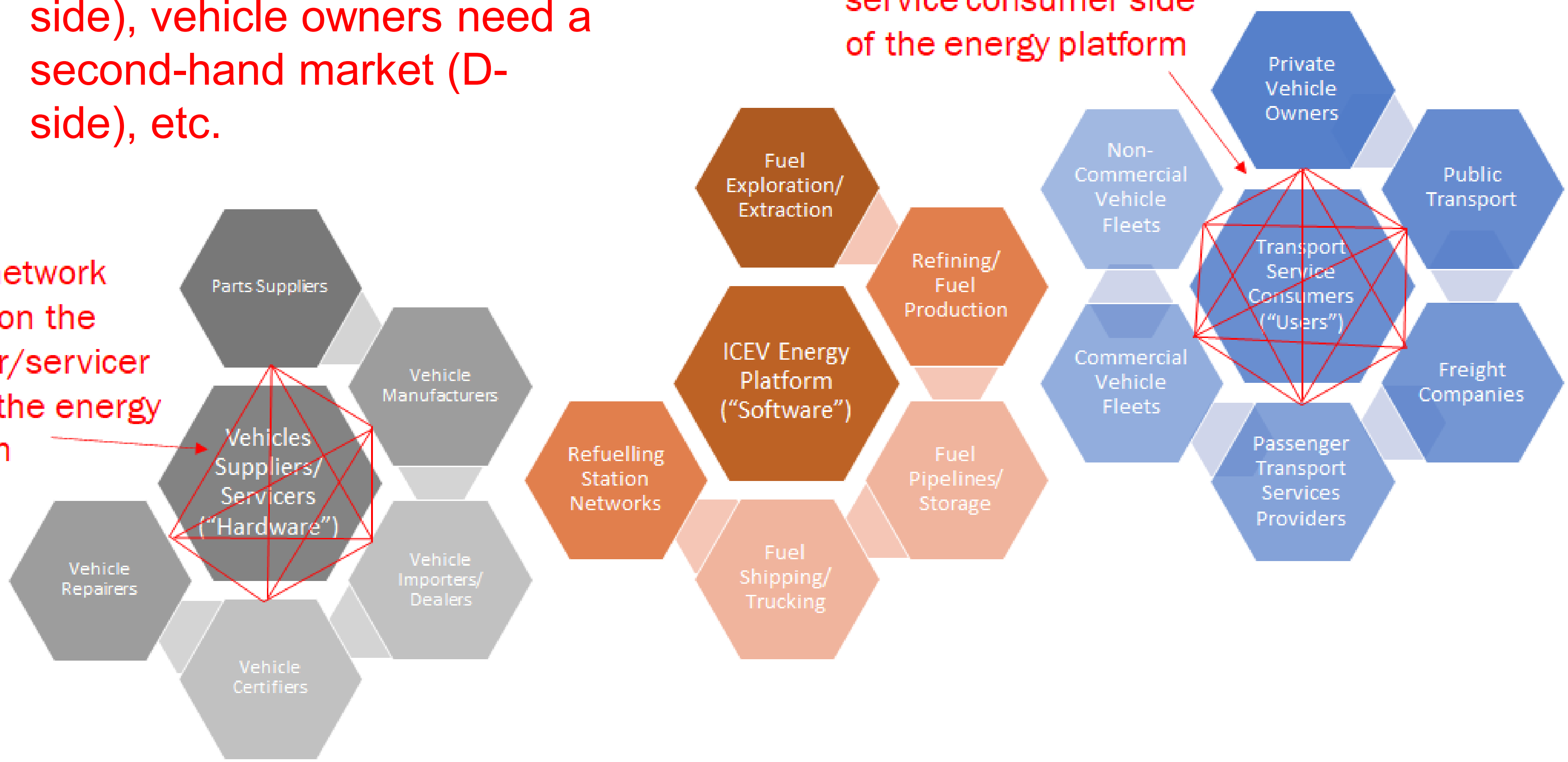


Key Challenge 2b – Platforms feature Scale Economies and **Network Effects** (cont'd)

E.g. vehicle manufacturers need vehicle servicers (S-side), vehicle owners need a second-hand market (D-side), etc.

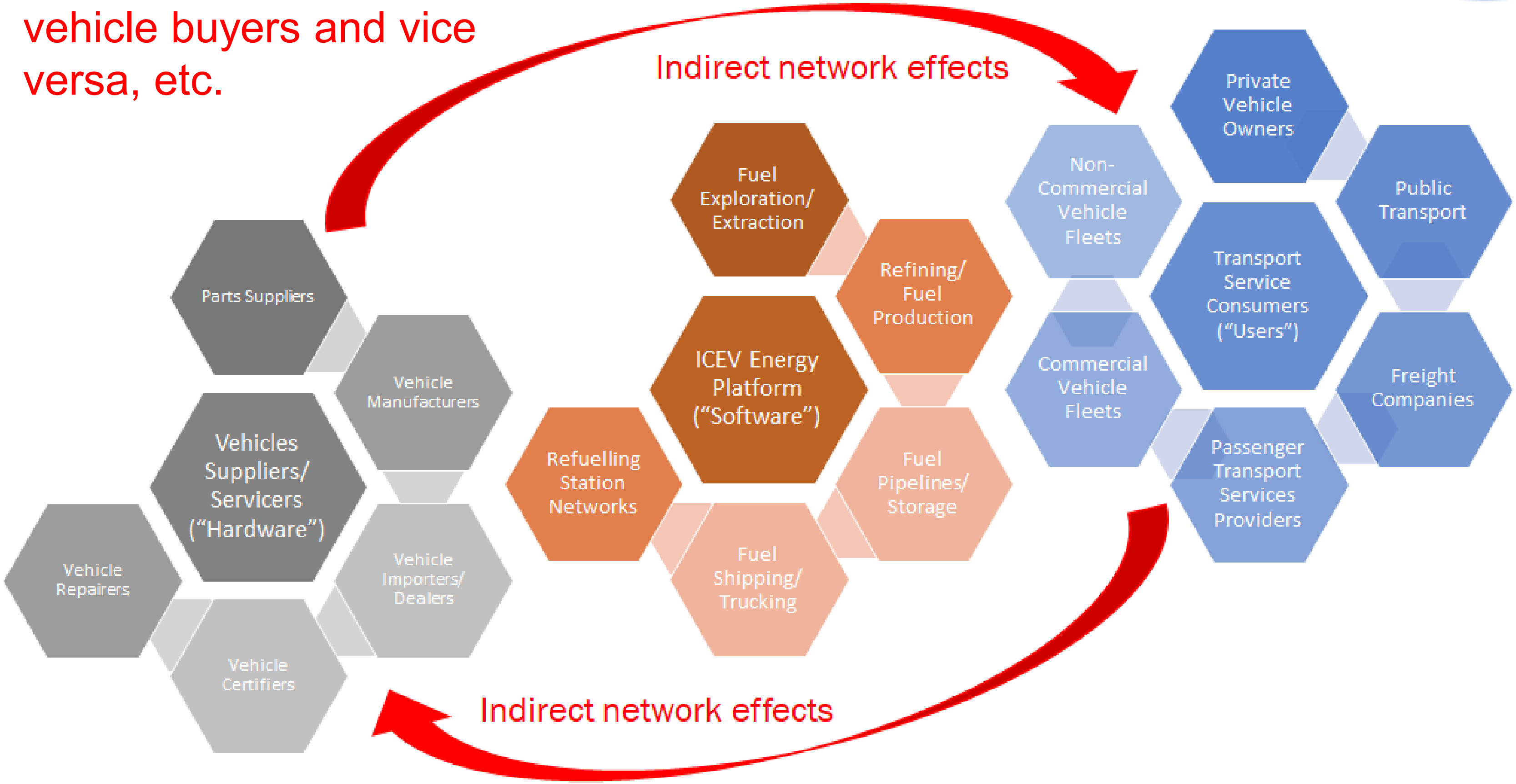
Direct network effects on the transport service consumer side of the energy platform

Direct network effects on the supplier/servicer side of the energy platform



Key Challenge 2b – Platforms feature Scale Economies and **Network Effects** (cont'd)

E.g. vehicle sellers need vehicle buyers and vice versa, etc.



Key Challenge 2c – Platforms feature Scale Economies and Network Effects (cont'd)

- Scale economies and network effects present particular challenges, e.g.:
  - **Path-dependence** – history matters (a lot);
  - **Coordination matters (a lot)** – chicken and egg problems abound, both within and across platform sides;
  - **Multiple equilibria** – some better for society than others, so which one do we want (since each is possible) and how do we get there?;
  - **Bigger is better** – tipping to monopoly is common;
  - Selective **pruning can *increase* network capacity;**
  - **Platform competition can result in inferior technologies being locked in ("excess inertia")!:**
    - E.g. Katz and Shapiro (1994), Economides et al. (2005), Weitzel et al. (2006), Brécard (2013), Onufrey and Bergek (2015), Greaker and Midttømme (2016), Krauthaus (2019), Filatrella and De Liso (2020), Halaburda et al. (2020), Amir et al. (2021).

Key Challenge 2d – Platforms feature Scale Economies and Network Effects (cont'd) …

Table 4.1 – Common Features of Technology Transitions

Feature	Description
Osborne effect	Consumers defer purchasing existing products in expectation that superior ones will soon be available (named after a computer manufacturer whose sales slumped after it prematurely announced an upcoming model)
Penguin effect[46]	Firms or consumers wait for others to be first to enter into a new area for fear of making a choice they then regret (like penguins not wanting to be first to dive into a sea in which predators might be lurking)
Sailing Ship effect[47]	Incumbent firms strategically improve their offerings when confronted with a potentially superior alternative, to delay or deter the alternative
Tipping[48]	The inclination for a market characterised by large economies of scale and/or strong network effects to end up with only one/few dominant alternative(s) despite starting with multiple competing alternatives
Matthew effect[49]	Related to tipping – larger or more successful alternatives prosper and dominate while smaller or less successful ones wither and die ("to every one who has will more be given, and he will have abundance; but from him who has not, even what he has will be taken away")[50]
Bandwagon and snob effects	Bandwagon effects refer to situations where consumers prefer to adopt a new technology when other users do (i.e. following the crowd). Snob effects refer to the opposite – some adopters may value prestige and exclusivity (e.g. adoption of high-cost new technologies as a signal of wealth, or only wanting to associate with an exclusive peer group). In this case mass adoption of a technology can cause such users to abandon it.
Vapourware	A product that is announced before it is available or even possible, often with the intention of convincing consumers to wait for the product rather than purchasing some rival product in the meanwhile and giving that rival product critical mass.

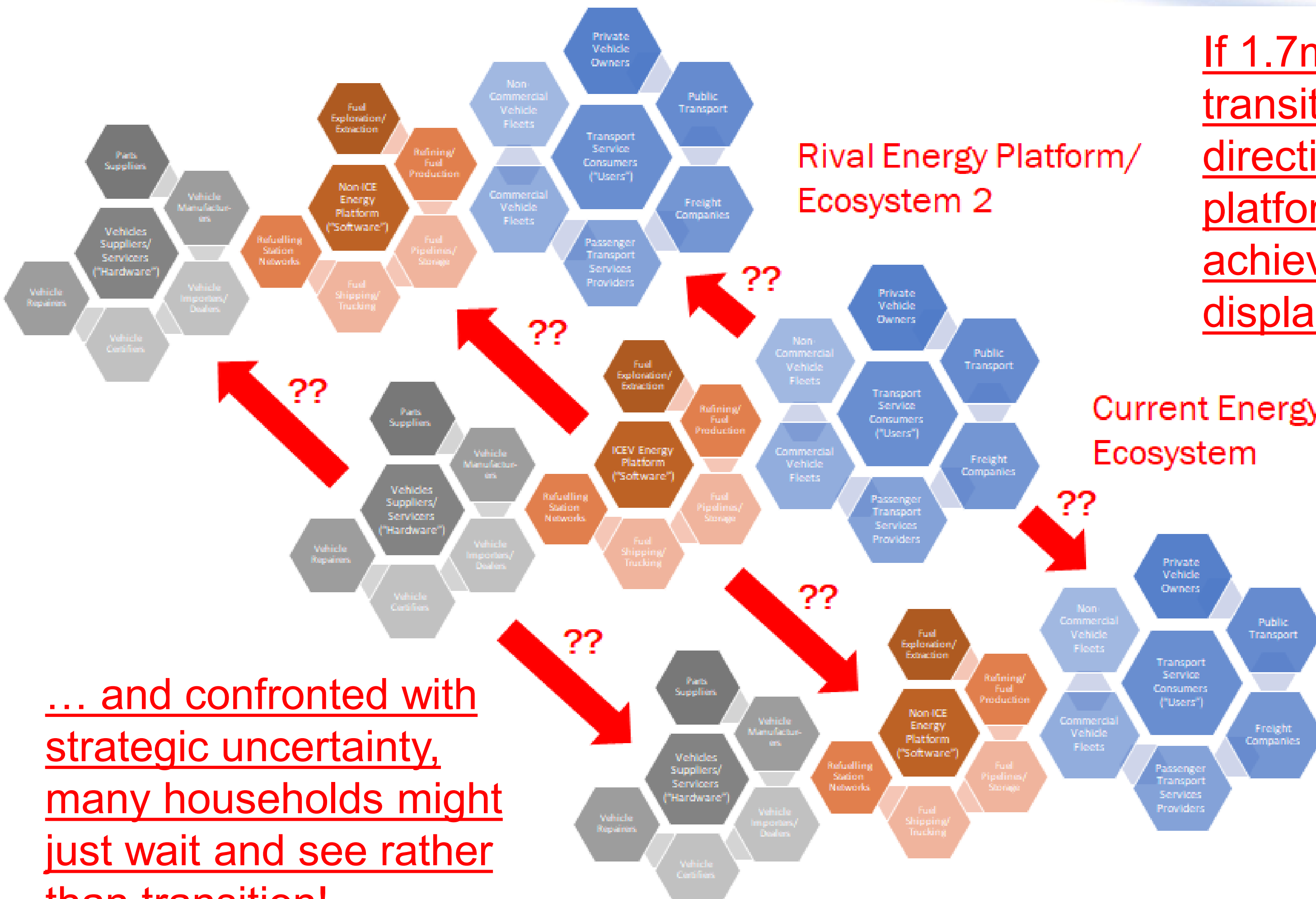
Technology transitions often feature scale economies and network effects, giving rise to a host of well-documented and sometimes counter-intuitive "effects" …

Key Challenge 2d – Platforms feature Scale Economies and Network Effects (cont'd)

Table 4.1 (cont'd) – Common Features of Technology Transitions

Feature	Description
Network paradoxes	E.g. in transport networks, adding road capacity or new roads can result in persistent congestion and/or longer travel times (Downs-Thomson paradox, Pigou-Knight-Downs paradox, Braess paradox).[51] In electricity systems, adding additional transmission capacity can reduce overall capacity due to how electricity flows through different constrained network paths (Kirchoff's laws)
First-mover advantage	Being first mover in a new area can create an incumbency advantage not available to later movers (e.g. a dominant market share – a.k.a. Stackelberg leadership in markets featuring imperfect competition among few firms)
Path-dependence	Related to first-mover advantage – the best decisions that can be made now are constrained by hard-to-reverse choices that were made in the past
Second-mover advantage	Sometimes a first mover helps to establish a new area only for a later mover to then dominate that area
Death spiral	A scenario in which an existing technology platform experiences user losses when a rival technology becomes sufficiently attractive. As users defect, the costs of sustaining the existing technology (e.g. if it is a network with large fixed costs) are passed on to a shrinking user base, and those costs also rise due to diseconomies of scale being introduced. Service quality can also suffer (e.g. due to the network being unprofitable to maintain). If the technology features network effects, user defections further reduce the benefits of the existing technology to other users. Such rising costs and prices, and declining service quality and network benefits, accelerate defections, with the process becoming irreversible if a tipping point is reached. The existing platform then dies.
Chicken and egg problem	Before investors in new technology platforms commit to making large and irreversible (e.g. network) investments, they want to know that there will be sufficient users of their platform (i.e. consumers, or suppliers) to make the investment profitable. However, users are reluctant to commit to using a new platform (e.g. buying specialised hardware that is not valuable unless the platform attracts sufficient other users) before they know platform investments will be made. This kind of "mutual penguin effect" can forestall platform take-off.

Key Challenge 3a – These Challenges are Exponentially Worse with Multiple Alternatives …



If 1.7m households transition in different directions then rival platforms struggle to achieve scale needed to displace incumbent …

… and confronted with strategic uncertainty, many households might just wait and see rather than transition!

Key Challenge 3a – These Challenges are Exponentially Worse with Multiple Alternatives … (cont'd)

Lock-in to ageing ICEVs is also induced by bans on imports of new and used ICEVs ("soft sunset") – visions of Cuba (but with rusty old Toyota's instead of Chevys).

Key Challenge 3a – These Challenges are Exponentially Worse with Multiple Alternatives …

- Challenges like these mean we can't presume competition will lead to the desired outcomes – and certainly not within 28 years (i.e. by 2050) if major infrastructure changes and millions of coincident consumer choices are required (plus 1000s of supplier choices).

- To non-economists this might sound heterodox, but to trained economists it shouldn't:
  - Competition only ever promises to deliver efficiency – *not timeliness, equity, or order* (and static efficiency at that, which supposes that transition costs and dynamic considerations don't matter …);
  - In any case, the Welfare Theorems rest on the absence – not preponderance – of distortions like scale economies and network effects;
  - A world with scale economies and network effects is second (third?) best – the Theory of Second Best is the better tool to reach for than the welfare theorems → for a "good" transition we need to be thinking about least-worst countervailing distortions (cf, e.g., chemo for cancer …).

Key Challenge 3b – These Challenges are Exponentially Worse with Inferior Alternatives …

Table 2.1 – Key Attributes of Clean Road Vehicle Technologies relative to ICEVs from the Vehicle User's Perspective

	BEVs	H_2Vs	Biofuels, e-fuels
Emissions	Lower if charged from renewables, but similar if charged from coal or gas	Depends on emissions content of electricity, but lacks embedded emissions of BEV batteries	Lower
Vehicle cost	Higher	Higher	Similar
Range	Less	Similar	Slightly less
Refuelling time	Longer	Similar	Same
Refuelling frequency	Greater	Similar	Slightly more
Refuelling infrastructure	Less	Less	Same
On-vehicle fuel storage	Less	Similar	Slightly less
Maintenance costs	Lower, except for battery replacement	Similar?	Similar
Acceleration	Greater	Similar/Greater	Slightly greater
Top speed	Limited by law	Limited by law	Limited by law
Towing capacity	Less	Similar?	Similar
Traffic congestion	Same	Same	Same
Travel times	Same	Same	Same

None of these alternatives represents a "slam dunk" transport revolution of the sorts that previously transformed transport!

<u>Key Challenge 3b</u> – … or <u>Inferior</u> Alternatives (cont'd) …

Rennie (1989, p. 82). Parade of all Christchurch electric vehicles in 1921.

The world (including New Zealand) has already been at the <u>crossroads between electric vehicles and other vehicle technologies</u>. Different this time?

Key Challenge 3c – … and Maybe Even with Revolutionary Transport Alternatives …

Could flying electric 'air taxis' help fix urban transportation?

Vertical Aerospace's air taxi, which is predicted to be in city skies in the mid-2020s. Photograph: Vertical Aerospace

Batteries with high energy-density, or hydrogen, could disrupt land and other transport modes as we know them (as well as urban form, work, leisure, business …)

Key Challenge 3d – … but Maybe Less So with “Mundane” Alternatives …

RAF sets world record for first successful flight powered by synthetic fuel

RAF completes first flight powered only by synthetic fuel, which could save up to 90 per cent of carbon per flight

Celine Wadhera • Wednesday 17 November 2021 07:18 • 16 Comments

Remember CNG/LPG cars in the 1980s …

… and imagine if our existing ICEV fleet and retail fuel supply chain could be <u>cheaply converted to hydrogen</u> …

Key Challenge 3d – … but Maybe Less So with "Mundane" Alternatives …

HW Richardson's truck fleet is on trial.

A trial to introduce hydrogen fuel, that is, in what chief executive Anthony Jones says is a first step towards an ambitious green future for the group.

HW Richardson Group, which has a 1300-truck fleet and 110 fuel stops across the country, would start its transition to the "future fuel" with the trial, Mr Jones said.

He hoped it would inspire other firms as he believed it could be the biggest change in the transport industry since the move from horse-drawn carriage to motor vehicles.

"We are a large part of New Zealand's transport [industry] — we have 1300 trucks in the road and our Allied Petrol business and our businesses in Australia; we distributed and sell a billion litres a diesel a year.

"We believe 100% hydrogen is the future and what we are trying to do is lead and make a meaningful change in the industry."

The company would invest $15 million to convert 10 of its trucks into dual-fuel hydrogen trucks and would establish a electrolyser in Gore to collect data on carbon emissions.

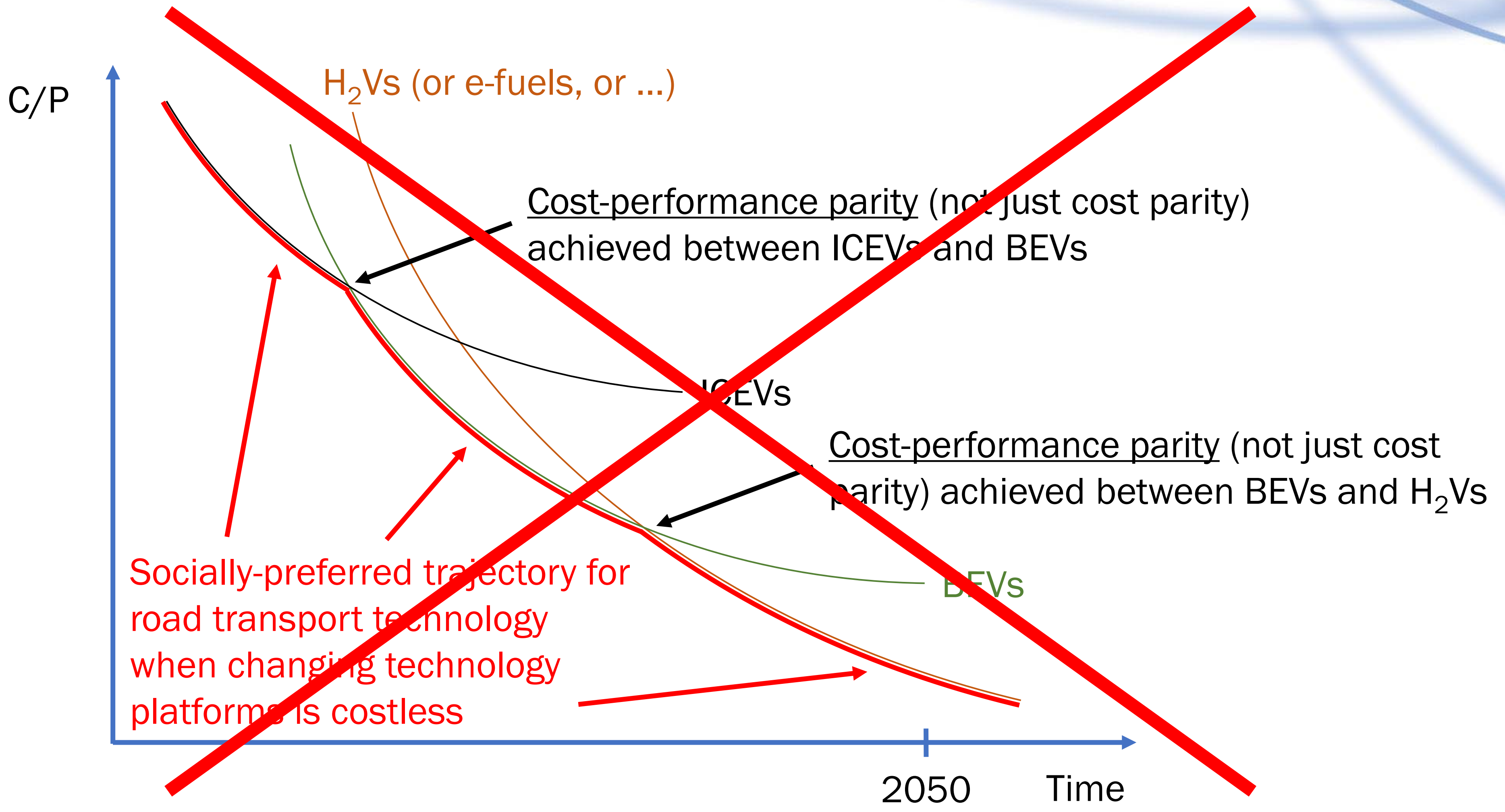
The idea was to have the trucks operating by April for an about six-month trial.

Mr Jones said while it might not the best commercial decision in the short term, it was the right pathway to take.

"We can offset 40% to 50% emissions of carbon with this.

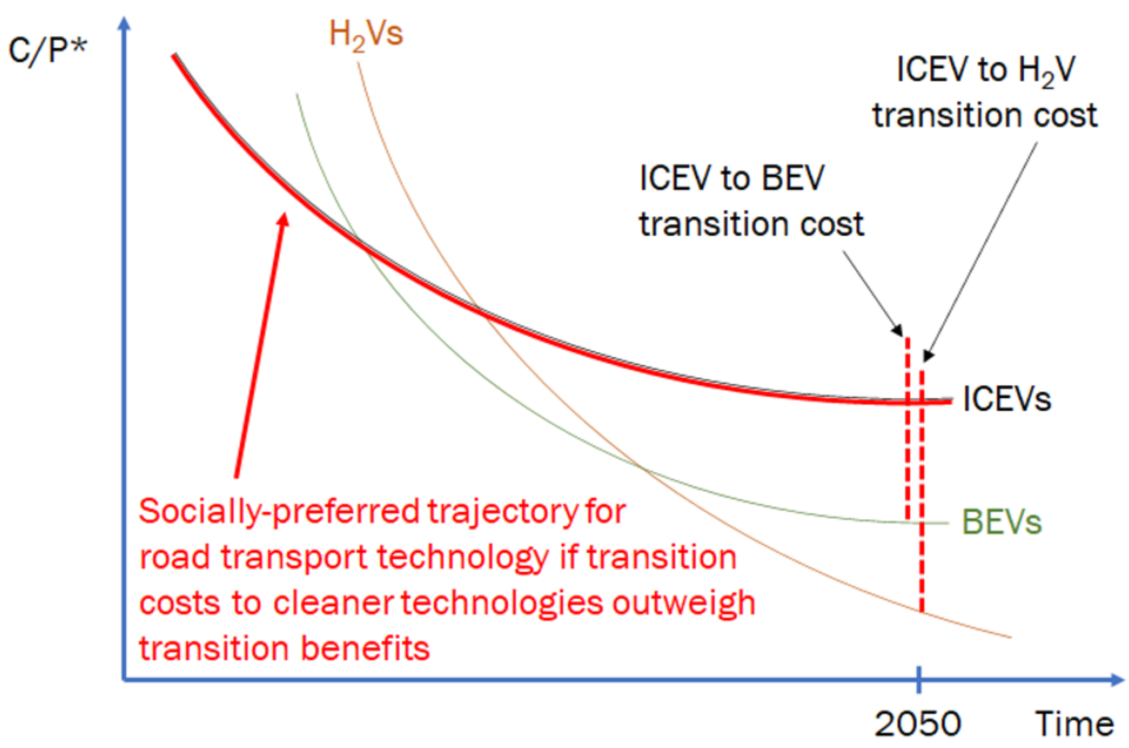
Source: text from https://www.odt.co.nz/regions/southland/truck-firm-trial-move-hydrogen

Key Challenge 4a – Cost Parity is Not Enough to Induce Migration – Performance Matters …



Key Challenge 4b – … But so do Transition Costs

Figure 4.6 – Lock-In to ICEVs when BEVs and H_2Vs Both Superior



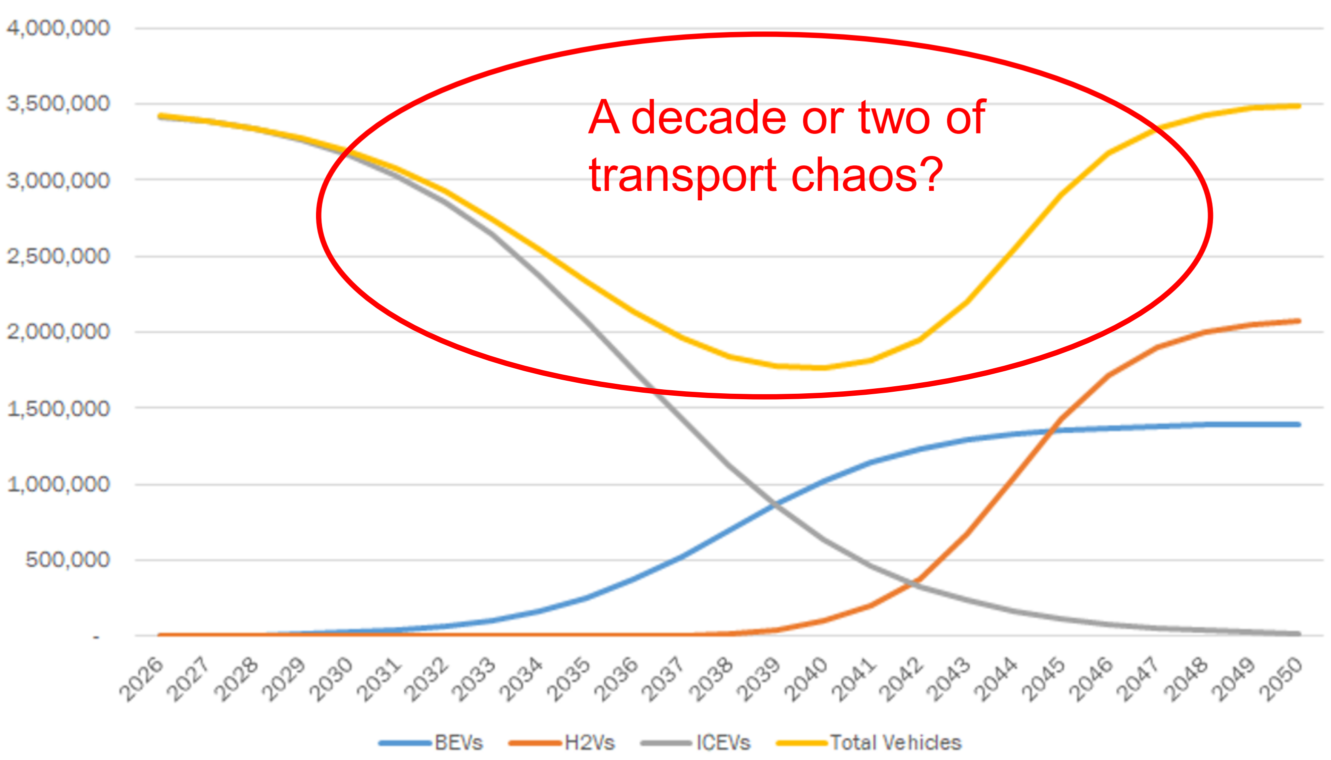
As before, it is not assured that the "best" technology wins! (though we can make choices affecting transition costs – see later)

Section 4.5 of the report shows how transition costs can give rise to multiple different transition scenarios.

* C/P = cost to performance ratio, accounting for transport technologies' non-environmental as well as environmental performance

<u>Key Challenge 5</u> – An Orderly Transition is by no means Assured

Figure 4.11 – Total Vehicle Numbers Crashing due to New Technology Vehicles Materialising More Slowly than Old Technology Vehicles are Disappearing



It's easy to destroy what already is. No amount of new legislation will magically build something to replace it (quickly, or in a synchronous way) – cf Brexit ...

Key Challenge 5 – An Orderly Transition is by no means Assured (cont'd)

Easy and quick.

Hard, complicated and slow – and not guaranteed to happen (in a timely way) just because something else got demolished.

Lessons from Past Transport Revolutions

- Think "dirt roads to canals", "canals to trains", "horses to ICEVs":
  - These transport revolutions transformed industry and society.
- History mattered, and there were lucky breaks as well as wrong turns.
- New technologies were adopted when they provided clear advantages relative to incumbent technologies – *speed, cost, reliability, freedom*.
- Incumbents fought back – improving their offerings, and seeking regulatory barriers to entrants (or support to remain competitive).
- Standardisation made a huge difference for uptake – e.g. non-standardised canals vs standardised railway lines and timetables.
- Only the wealthy could afford private transport (excepting bicycles) – until mass production and standardisation (Ford's Model T …).
- Chicken and egg problems were resolved by vested interests (i.e. industrialists) building new infrastructures for their own benefit.
  - Investment manias and "lost shirts" followed early successes.

Lessons from Past Transport Revolutions (cont'd)

Preconditions to New Zealand's Transition

- Small, low-density population – hard to achieve scale economies, or large network effects.
- Under-developed public transport, and reliance on private vehicles.
- Relatively low-income population – slow vehicle fleet renewal.
- Reliance on imported used right-hand drive vehicles from Japan.
- Electricity system largely renewable, but with limited storage.
- No significant vehicle manufacturing, and limited heavy industry.
- Few local organisations with large balance sheets and infrastructure development expertise.

Unlike other developed economies, New Zealand might be more reliant on legacy infrastructure owners (and/or government) than on large industrialists with vested interests to lead the development of clean energy infrastructures (with the conversion of existing infrastructures likely to be cheaper than building new ones anyway) …

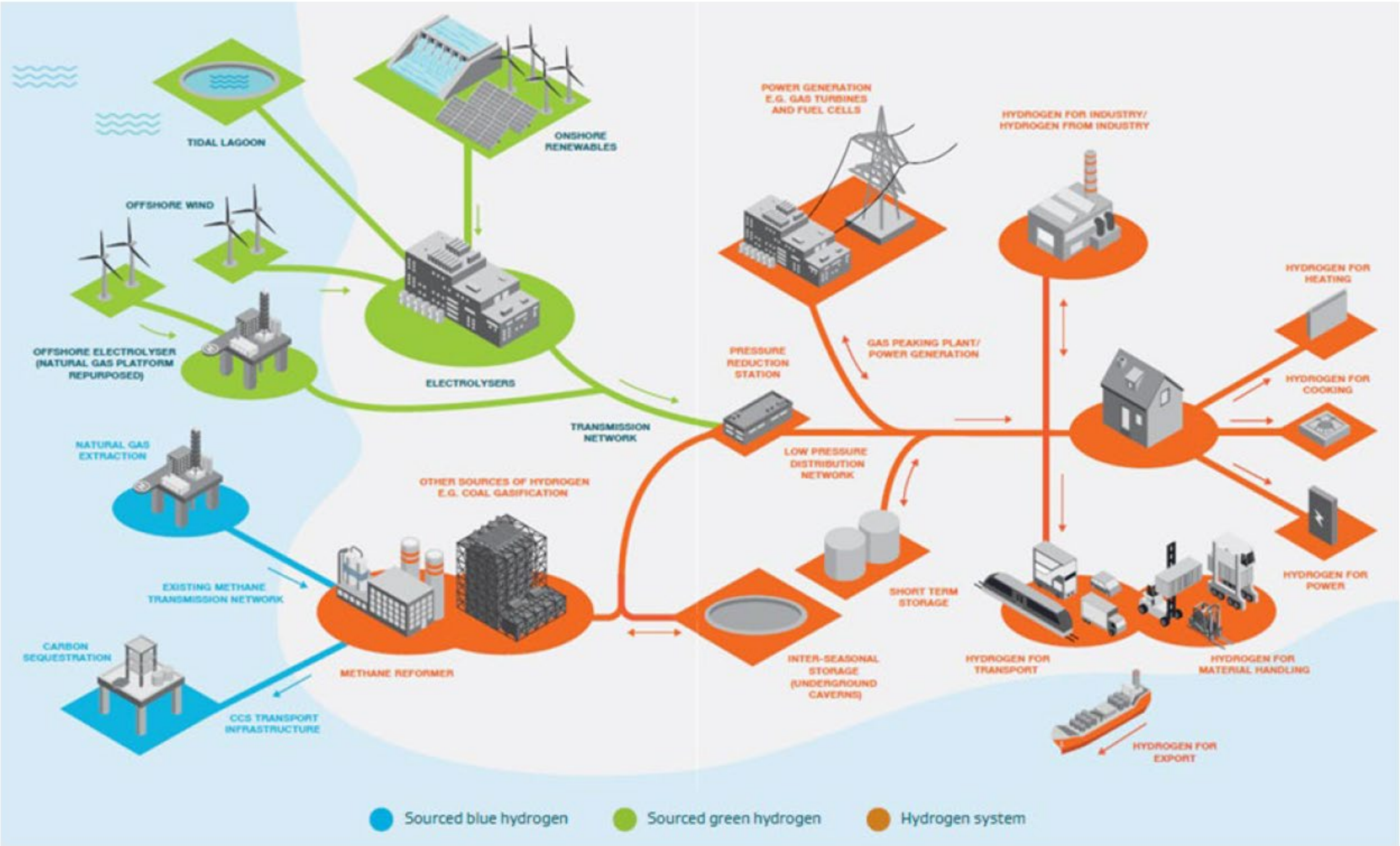
Preconditions to New Zealand's Transition (cont'd)

Table 5.1 – Requirements for Establishing BEV and H_2V Energy Ecosystems

	BEV Ecosystem	H_2V Ecosystem
New hardware	BEVs, BEV home chargers.	H_2Vs, gas heaters/appliances.
Retrofitting possible	Not currently.	Possibly – gas heaters/appliances, maybe even ICEVs to H_2ICEVs.[82]
Requirements for low-emissions fuel supply	Increased renewable electricity generation, plus backup storage (possibly from hydrogen production and storage, but not BEVs)[83] to manage intermittency.	Increased renewable electricity generation for green hydrogen (no backup required since stored hydrogen provides backup itself). Alternatively, CCS for domestically produced blue hydrogen, or ability to import green/blue hydrogen.
Transmission infrastructure	Can potentially use existing high-voltage grid for required long-distance electricity transportation.	Could repurpose existing gas transmission in North Island, and system for getting bottled gas to South Island – and also gas storage capacity.
Distribution infrastructure	Local networks need reinforcing for BEV charging peaks – less so with "smart charging", or if rooftop PV becomes widespread, (provided PV combined with storage for time-shifting supply and use).	Could repurpose existing North Island distribution infrastructure, and bottled gas distribution system in South Island.
Refuelling infrastructure	Private slow/fast chargers required at homes/apartments and workplaces. Public slow/fast chargers required at shops, dedicated charging sites, etc.	Existing service station network could be repurposed (augmenting current gas supply capacity, or adding additional such capacity).
Network effects	BEV uptake makes BEV charging networks more viable and vice versa.	H_2V uptake makes modifications to existing refuelling infrastructure (or new such infrastructure) more viable, and vice versa.
Economies of scale/scope	Yes – V2G support services to electricity distributors, synergies with PV systems (using BEVs as storage), etc. Possibly greater capacity utilisation of distribution networks (and/or diseconomies of scale).	Possible V2G support services to electricity distributors (e.g. from FCEVs). Possible synergies with PV systems (small-scale electrolysis). Greater capacity utilisation and economies of scale for hydrogen infrastructure used for heavy transport, non-land transport, commercial/industrial heating, etc.

Preconditions to New Zealand's Transition (cont'd)

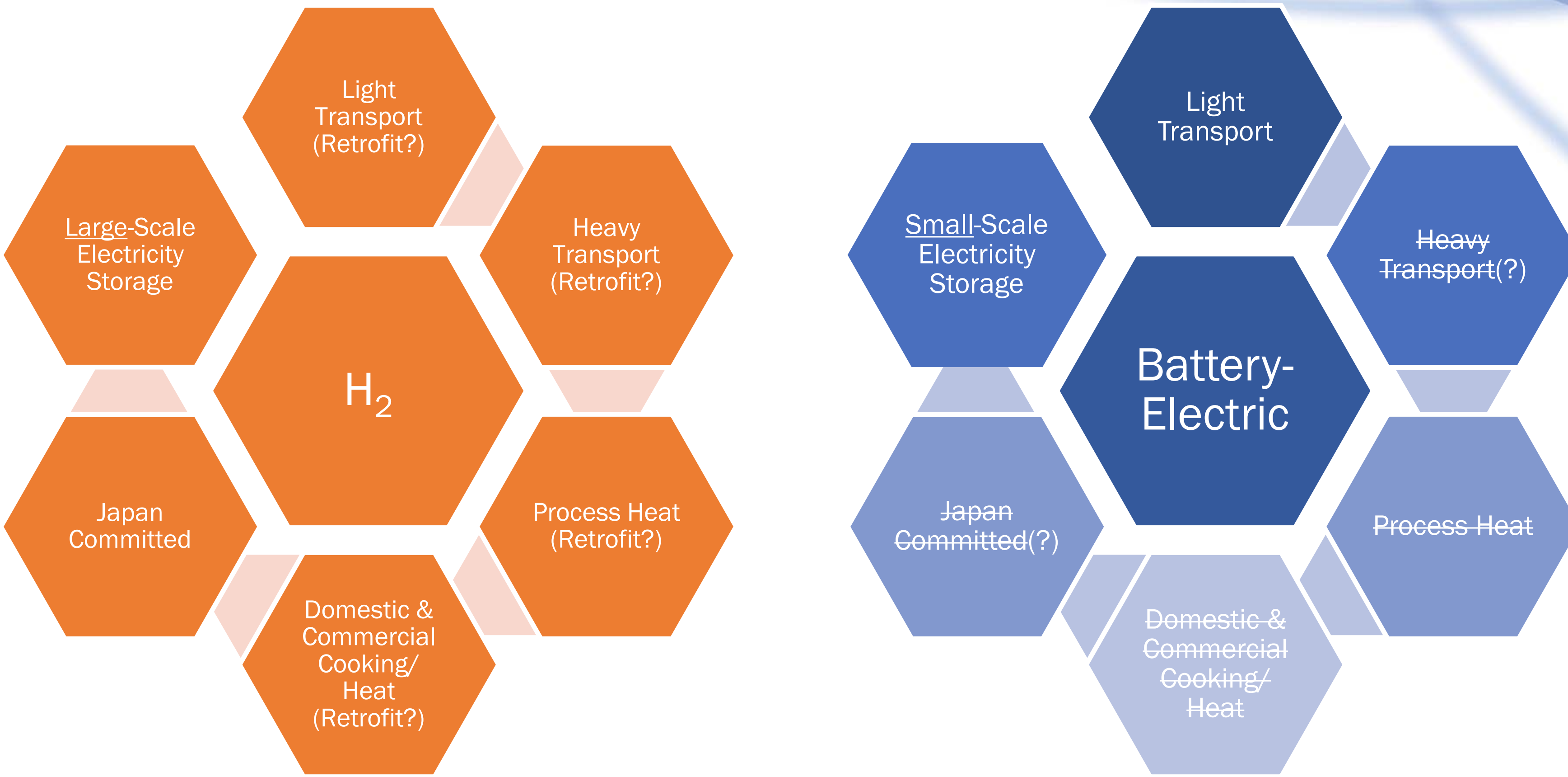
Figure 2.3 – A Possible Hydrogen Ecosystem for New Zealand



New Zealand's Key Policy Questions

- See Section 5.4 of the report for discussions of the following:
  - What are the trade-offs in waiting to see which clean technologies come to dominate, and what factors affect those trade-offs for New Zealand?
  - What are the trade-offs in committing to a particular clean technology, and what factors affect those trade-offs for New Zealand?
  - How should critical trade-offs in the transition be determined?
  - Is it sufficient for New Zealand to rely on "push" measures to achieve the desired transition, or are "pull" measures required too?
  - Should transition policy prioritise responses by smaller decision-makers or large ones, and if so, which?
  - What level of coordination is required to synchronise the demise of emitting technologies and diffusion of low-emissions technologies?
  - What role for vested interests in the transition?

On “Picking Horses” – Which Energy Platform has the Most “Legs” (And Least Regret)?



New Zealand is heavily dependent on used Japanese right-hand drive vehicles. Which way is Japan going? Heavy transport? How far will Tesla’s vision take us?

On "Picking Horses" – Which Energy Platform has the Most "Legs"? (cont'd)

The fuel that could transform shipping

London-Auckland in zero emissions hydrogen-powered jet? UK-backed concept design unveiled

Siddharth Philip · 07:08, Dec 07 2021

AEROSPACE TECHNOLOGY INSTITUTE/SUPPLIED

The FlyZero concept envisions a plane carrying 279 passengers from London to Auckland with one stop

HYUNDAI New Shop Trucks Specials Fleet About Used Contact

Hyundai Motor and H2 Energy to bring the world's first fleet of fuel cell electric trucks into commercial operation

New Zealand's Policy Levers (Report Section 6)

Table 6.1 – Policy Levers that might be used to Accelerate the Transition to Net-Zero Emissions

	"Push" levers (Discouraging emissions)	"Pull" levers (Encouraging low-emissions)	General levers
Demand-side levers (interact with supply-side due to indirect network effects)	Price measures: • Emissions pricing (reflecting network effects as well as environmental costs) • Levies on emitting hardware	Price measures: • Clean fuel subsidies • Clean hardware subsidies • Parking or toll road subsidies for clean transport users	• Creating coordination focal points for hard-ware suppliers, con-sumers/users, and infrastructure pro-viders • Increasing commit-ment power of long-term policies (e.g. independent policy-making and imple-mentation) • Wider regulatory/ policy coordination – urban design, trans-port, energy, etc • Safe harbours from competition law prohibitions on
	Non-price measures: • Sunset clauses (hard, soft) • Technology targets/ mandates	Non-price measures: • Sunset clauses (hard, soft) • Technology targets/ mandates • Certification/consumer information • Hardware leasing, or guaranteed buy-backs/trade-ins • Solutions for new technology end of life (e.g. battery recycling)	

The good news is that we have many <u>demand-side</u> (push and pull) levers …

New Zealand’s Policy Levers (Report Section 6)

Table 6.1 – Policy Levers that might be used to Accelerate the Transition to Net-Zero Emissions

	“Push” levers (Discouraging emissions)	“Pull” levers (Encouraging low-emissions)	General levers
Supply-side levers (interact with demand-side due to indirect network effects)	Price measures: • Emissions pricing • Levies on emitting hardware	Price measures: • Subsidies or co-investments for new infrastructure	prohibitions on desirable industry coordination • Regulatory forbearance for whole-of-life infra-structure pricing – e.g. sub-cost initial pricing to accelerate uptake, followed by higher later pricing to achieve required life-time fair returns)
	Non-price measures: • Sunset clauses (hard, soft) • Technology targets/ mandates • Progressive bans on emitting uses of fossil fuels, or on fossil fuel exploration • Coordination/coop-eration measures	Non-price measures: • Targets/mandates for minimum clean infrastructure capacity and service levels • Franchise bidding for monopoly rights to develop clean infrastructure(s)	

… as well as many supply (push and pull) levers to manage the net-zero transition → see Section 6 for details.

For now, focus on one very “big idea” – franchise bidding …

Big Idea? – Franchise Bidding Approach

- If vested interests don't champion the transition, we could be left facing incumbents whose interest is to deter the transition:
  - Competition between alternative new technologies actually helps them!
- Possible solution is to fix the retirement of the incumbent technology, but also auction rights to be the <u>monopoly</u> provider of the alternative technology (subject to specified service levels, price controls, etc):
  - **Changes the payoffs of the incumbents** – gives them a shot at realising upside from the new and not just losses from the old;
  - Might still be more profitable to deter the transition, **but if rivals get the upside and incumbents just face the downside … (prisoner's dilemma)**;
  - Could recycle auction proceeds to subsidise hardware uptake;
  - Monopolist can use initially below-cost pricing and make profits later.
- <u>Expect incumbents to win</u> – already have a massive head start …
- <u>Precedents</u> – New Zealand's UFB initiative, toll road PPPs, …

Take-Home Messages

- We can't just retire existing technologies and assume new ones will fill the gap in a timely and synchronised way.
- The transition to net-zero is fundamentally about migrating from a compelling incumbent technology platform to competing alternatives that either don't yet exist, or are currently inferior:
  - Choices we make can make the alternatives more compelling.
- There is no guarantee that platform competition will yield the outcomes we want/need:
  - If we want clean technologies to prosper, we need to do some selective pruning – of new technologies as much as old ones.
- Unless government wants to "go large" on clean energy infrastructures, we need large vested interests to take the lead – either industrialists, or legacy infrastructure owners:
  - We have policy levers to make it in their self-interest to do so.

Slides, and full report available at: https://www.cognitus.co.nz/publications

Possible Next Steps

- Do illustrative and/or formal scenario modelling to demonstrate how different policy choices affect the take-off of required clean energy infrastructures, e.g.:
  - BEVs only;
  - Hydrogen only;
  - Both hydrogen and BEVs;
  - Dark horses – hybrids, hydrogen retrofitting, low-cost flight …
- Spend more time to look at the report's analysis and findings.
- Socialise the report's ideas with target audiences locally and abroad.

Report available at: https://www.cognitus.co.nz/publications