Economic Costs of Rapid Transitioning to Hydrogen Fuel Cell Light Vehicle Fleets in Japan and New Zealand

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Introduction

- We examine the economic impacts of rapid replacement of the conventional light vehicle (CV) fleet with a hydrogen fuel cell (HFCV) fleet in the two contrasting island nations of Japan and New Zealand. These two countries were chosen as they represent diverse examples of GDP per capita and population growth.
- Japan has a GDP per capita (2013) of US$38,633 and negative population growth 2011-2013 of -0.89% while New Zealand has a GDP per capita of US$16,240 and a positive population growth rate of 0.9%.

Methodology

- Establish a life cycle economic model for HFCV and CV fleets utilising capital, operating, maintenance and depreciation data.
- Apply net present value economics to determine comparative life cycle costs.
- Perform an economic analysis for each owner of the same vehicle.
- Apply HFCV penetration rates of 30% to 50% for early time growth using a modified sigmoid curve.
- Determine the cost of avoided CO2 emissions.
- Determine new and used vehicle subsidies.
- Determine cumulative vehicle subsidies.

Methodology (cont.)

- Early time growth rates for HFCVs of 30%, 40% and 50% were chosen based on three case histories.
  - Ford Motor Company 1903 to 1925 excepting the World War of 1914-1918 grew at 37%.
  - Toyota Prius from 1998 to 2010 grew at 32.6%.
  - Nissan Leaf production for 2011-2014 grew at 36.4%.

- In 2021 HFCVs estimated for Japan at 75,000; NZ at 500.

Methodology (cont.)

- The sigmoid function calculates the number of HFCVs (V^*) as a function of the total vehicle fleet (V_{tot}) and has the form:

$$V^* = \frac{V_{tot}}{1+e^x} \quad where\ x = (C_1 r + C_2)(C_3 r^2 + C_4 r + C_5 - Year)$$

notation

V^* = HFCVs;

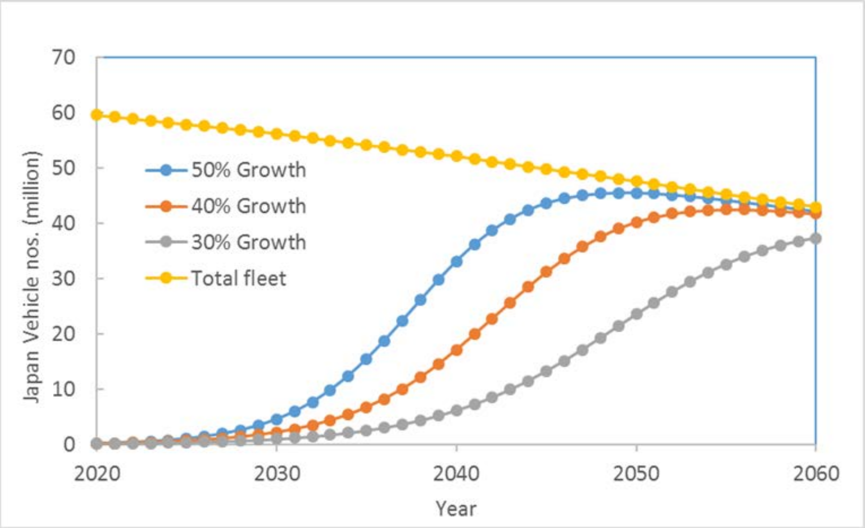
V_{tot} = total vehicles;

C_i = constants;

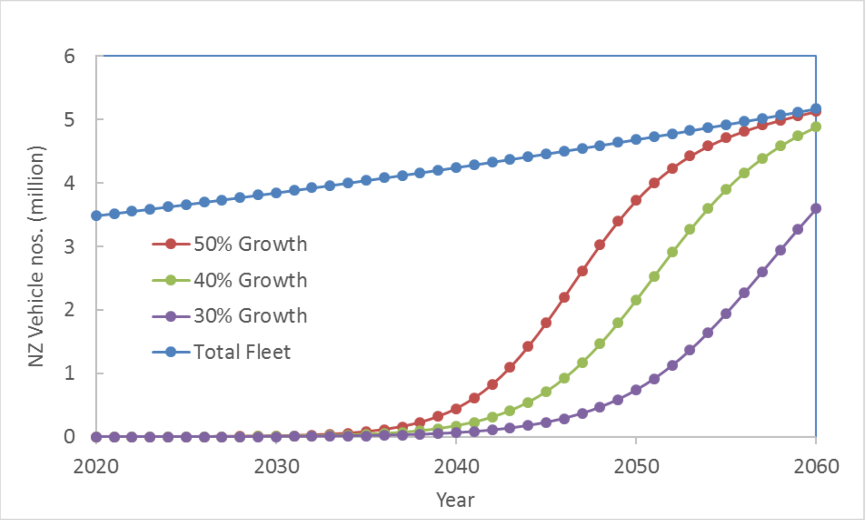
r = growth rate (fraction)

Exogenous market penetration of HFCVs

Japan



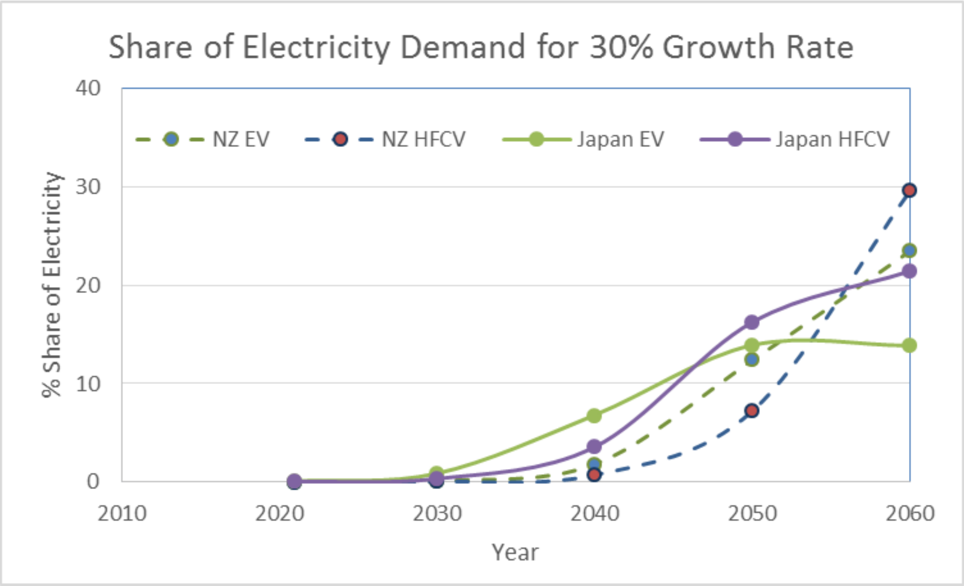
New Zealand

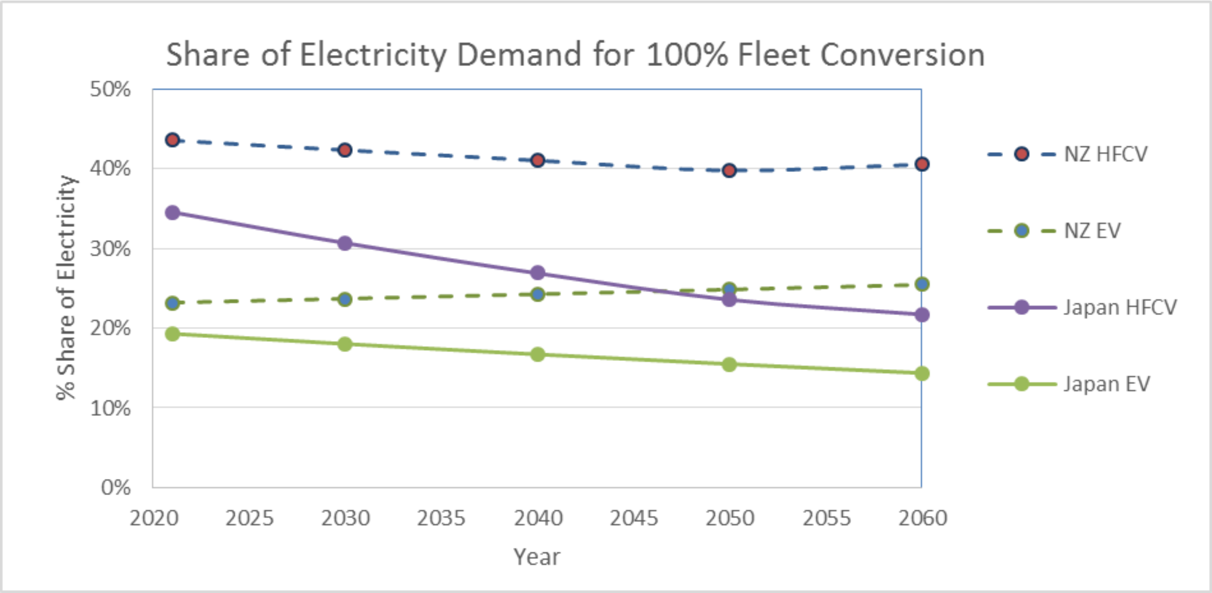


Key data for HFCV and CV Comparison

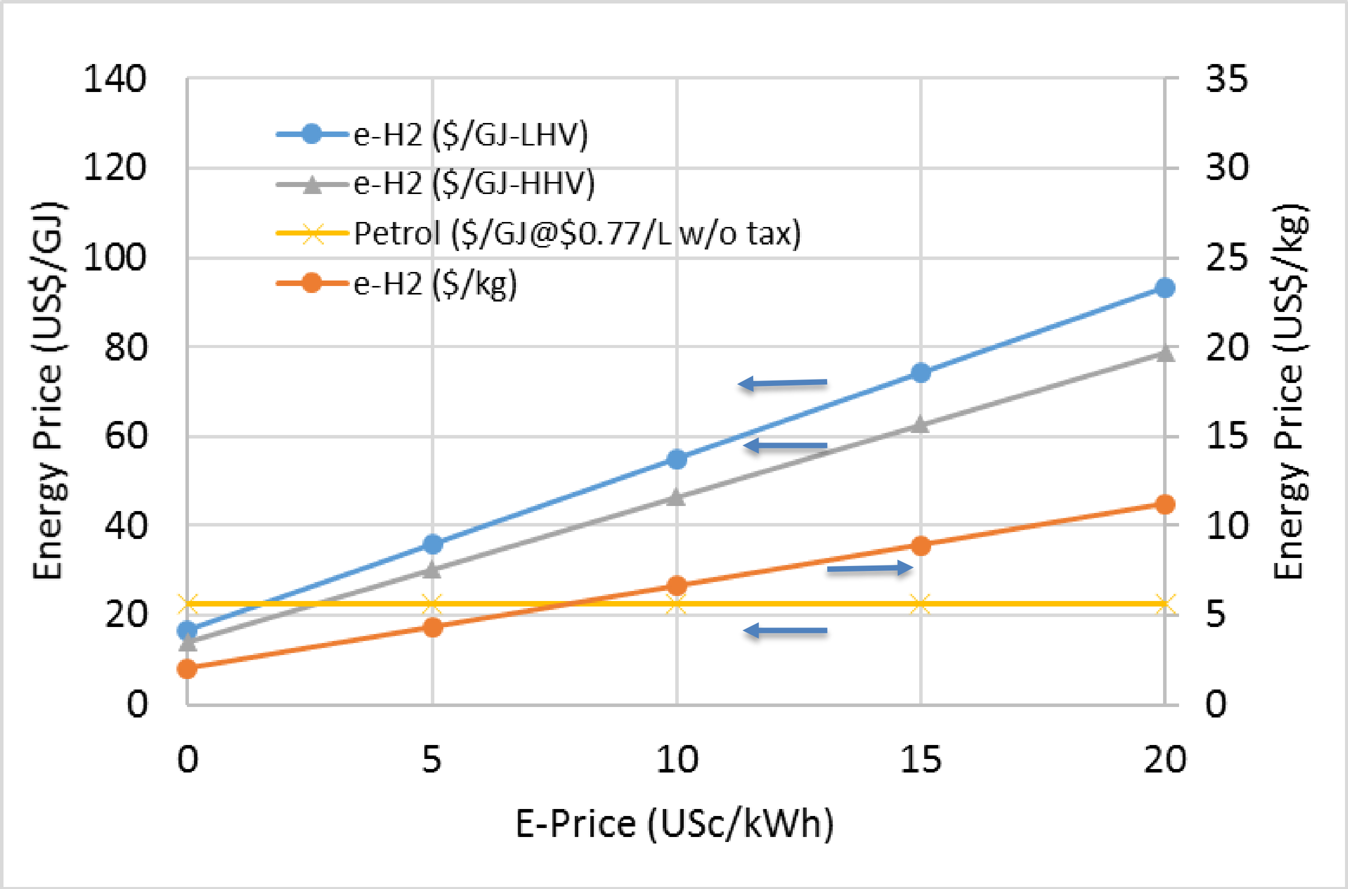
Item	Japan	New Zealand
Ave annual travel distance (km)	9120	11393
Ave fuel economy of new CVs (km/L)	16.64	14.93
Ave fuel economy of used CVs (km/L)	13.57	11.76
Ave fuel economy of FCVs (km/kg)	100.00	100.00
Ave individual ownership period (yr)	7.50	4.79
Ave new vehicle life (yr)	12.76	18.70
2015 Fuel cell cost $/kW	345	345
Fuel cell cost in 2030 US$/kW	49	49
Annual main & service costs of CV-FCV (US$)	148	148
Annual FCV price depreciation	0.21	0.16
Annual CV price depreciation	0.12	0.12
Discount rate for new vehicles (NPV)	0.03	0.03
Discount rate for used vehicles (NPV)	0.09	0.09
Gasoline price (US$/L)	0.87	0.77
Hydrogen Price (US$/kg)	12	12
Electrolyser efficiency 2050 (kWh/kg)	44	44
US ex rate average 2012-16	0.0095	0.74
Gasoline CO2 emissions (kg/L)	2.32	2.36
Electricity CO2 emissions (kg-CO2/kWh)	0.54	0.14
Annual reduction in electricity CO2 emissions	0.97%	7.18% (to 2035)
Annual Fuel Expense ($US)		
New CV	479	588
Used CV	588	746
Fuel cell size kW (Mirai)	114	114
FCV capital cost in 2030 ($US)	23815	23815
CV capital cost in 2030 ($US)	18201	18518

Electric Energy Requirements





Hydrogen Production from Distributed Electrolysis



Capital costs at 2020 derived from USDOE http://www.hydrogen.energy.gov/h2a_production.html
Based on 1500 kg H2 per day and includes O&M and decommissioning

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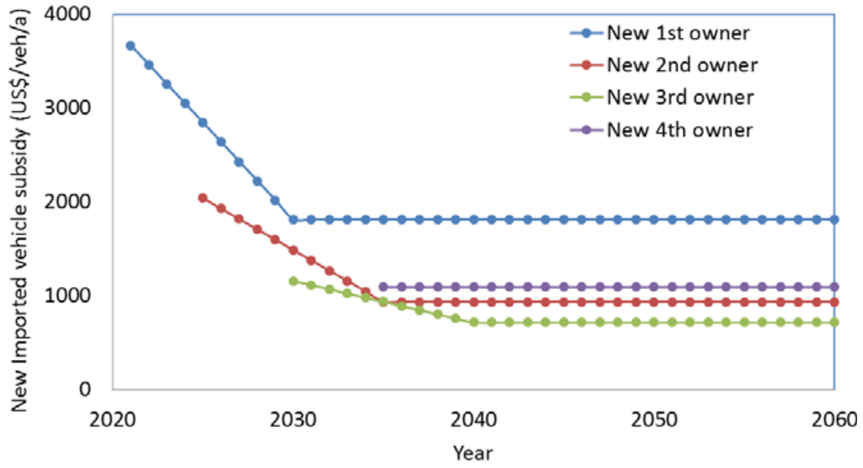
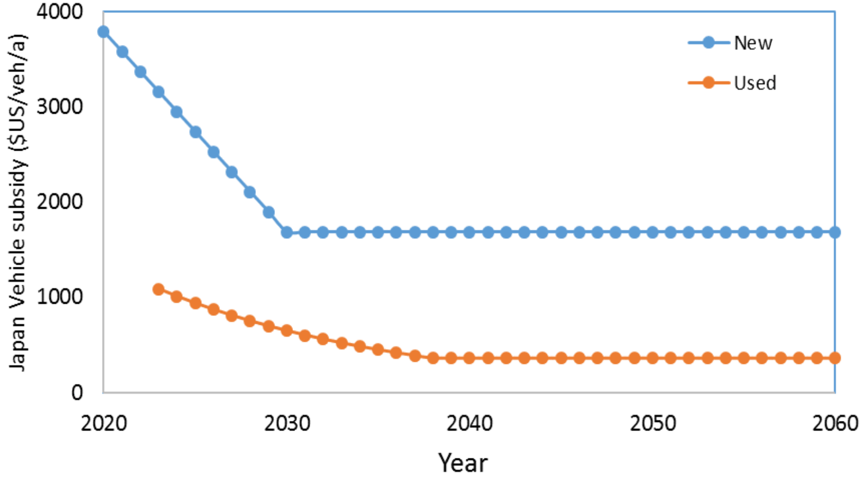
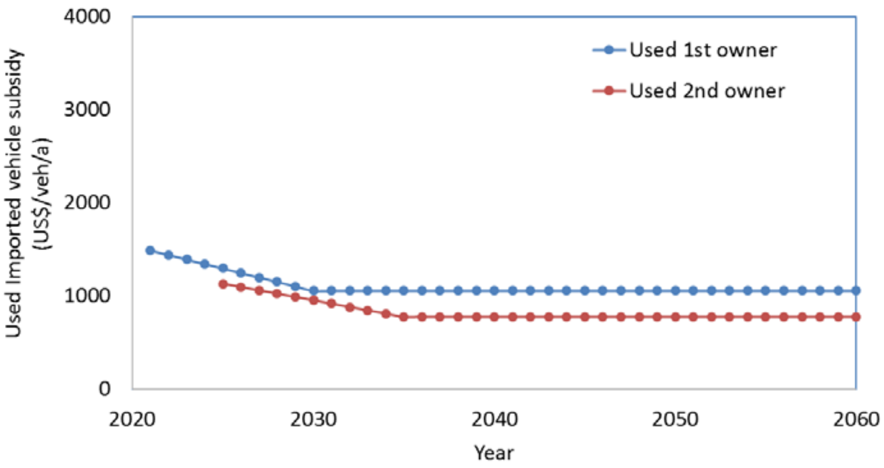
Used and New Vehicle Subsidies

New Zealand



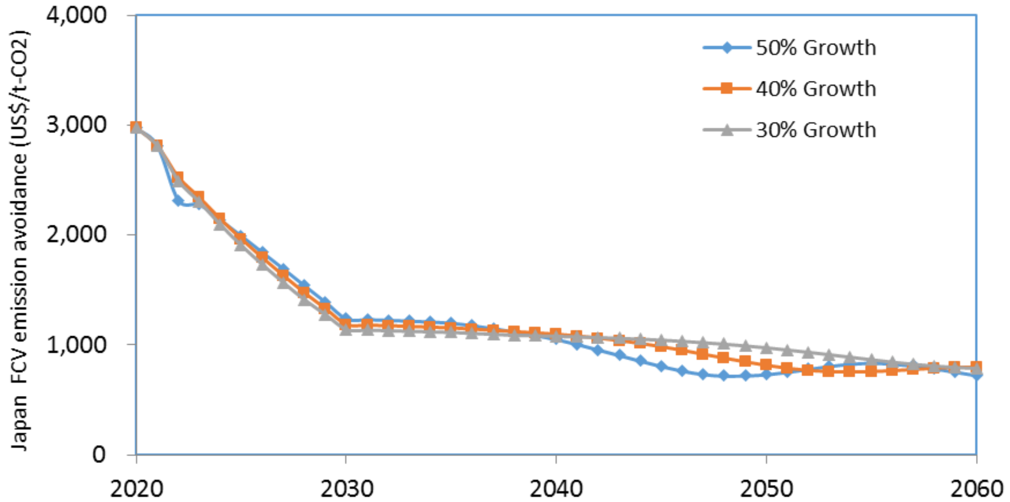
Japan



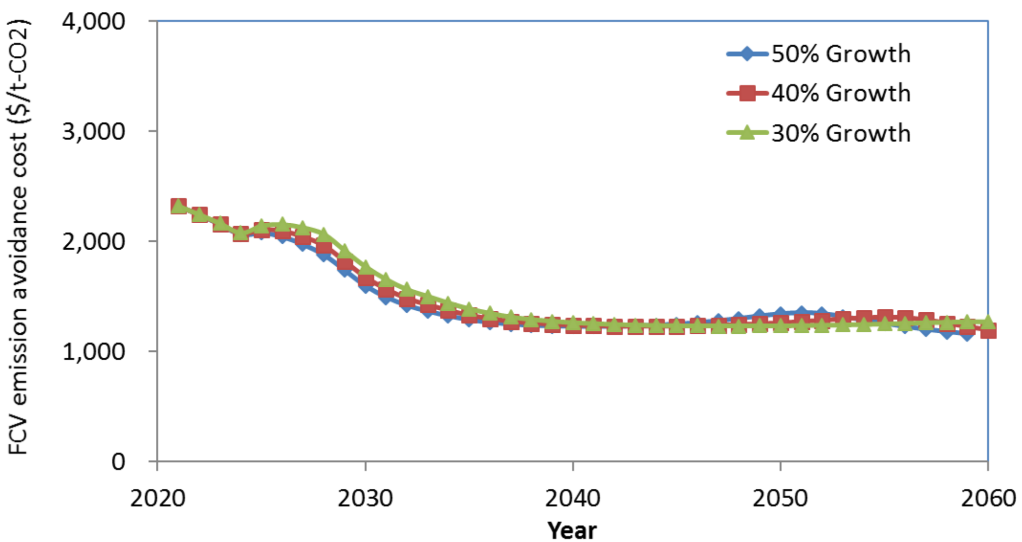


Emission Avoidance Costs

Japan



New Zealand



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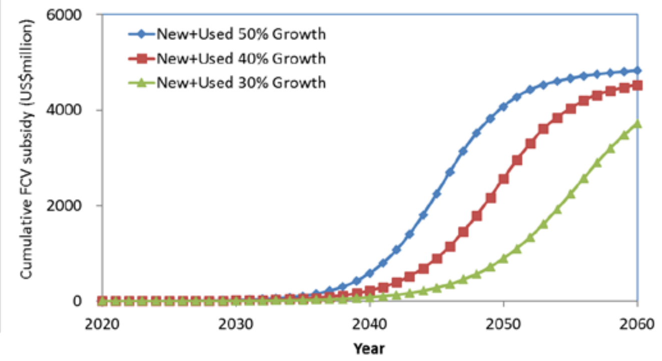
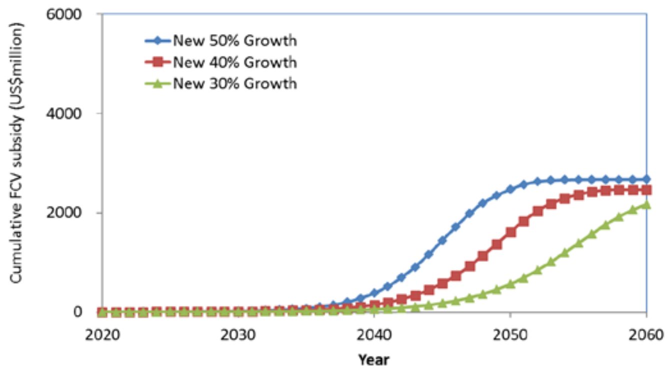
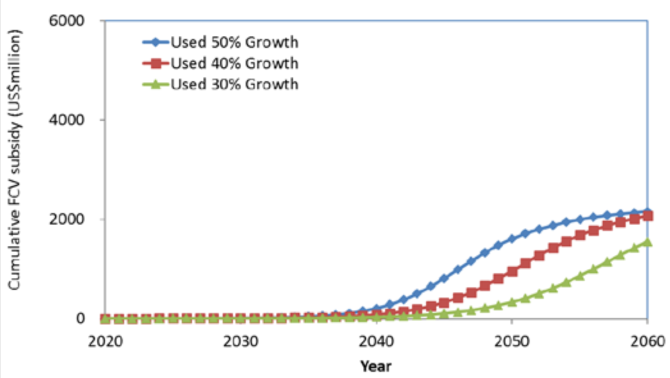
Cumulative Vehicle Subsidies

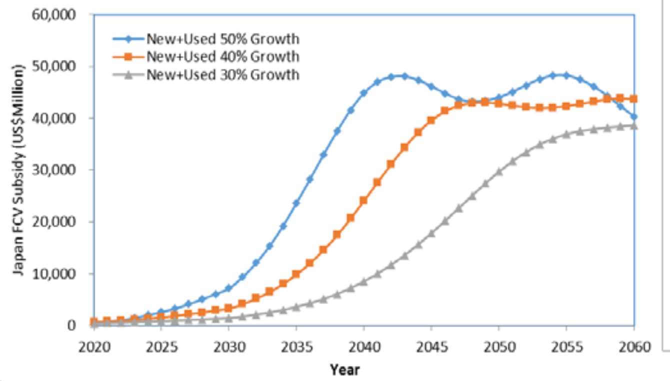
New Zealand

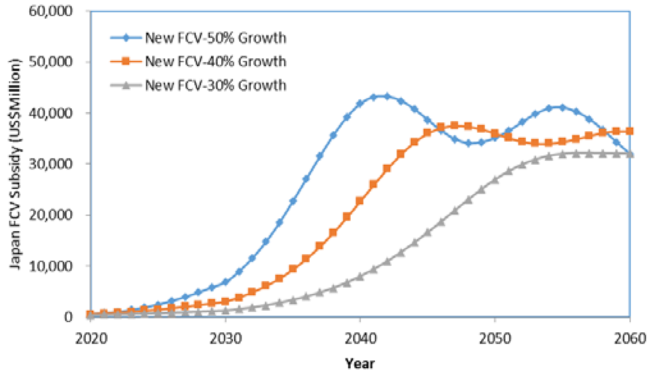


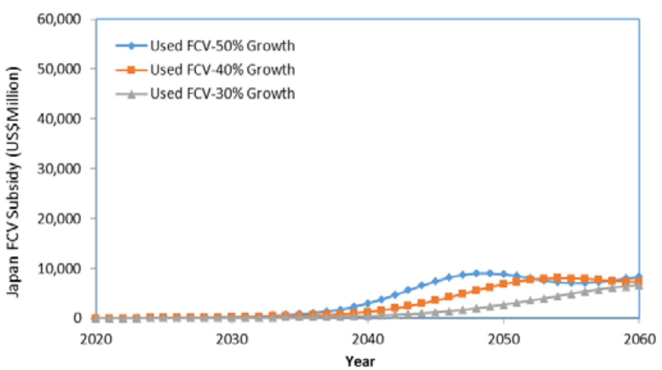




Japan





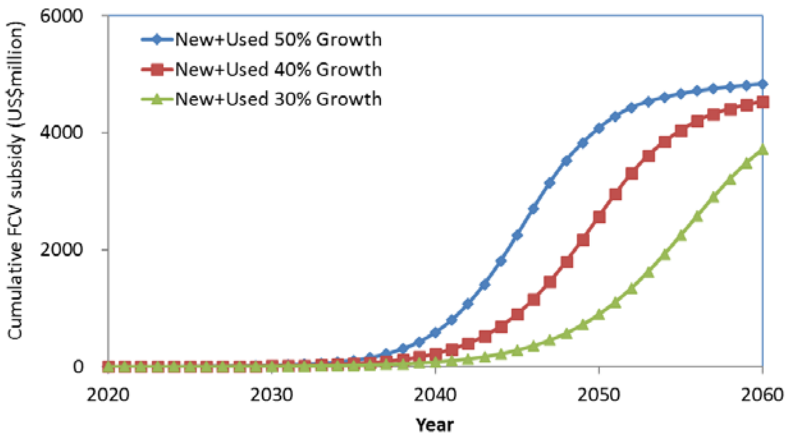


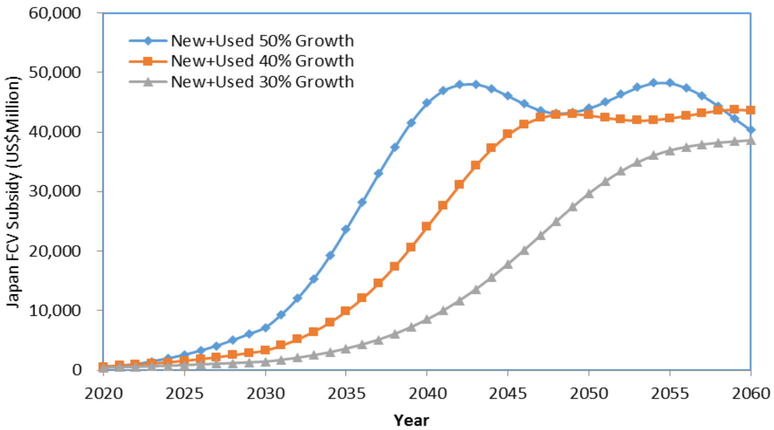
Cumulative Subsidy for Low Cost Hydrogen

New Zealand

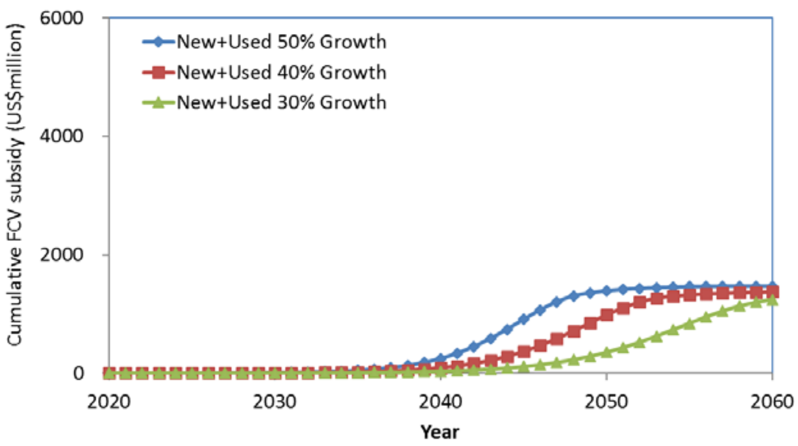
Japan

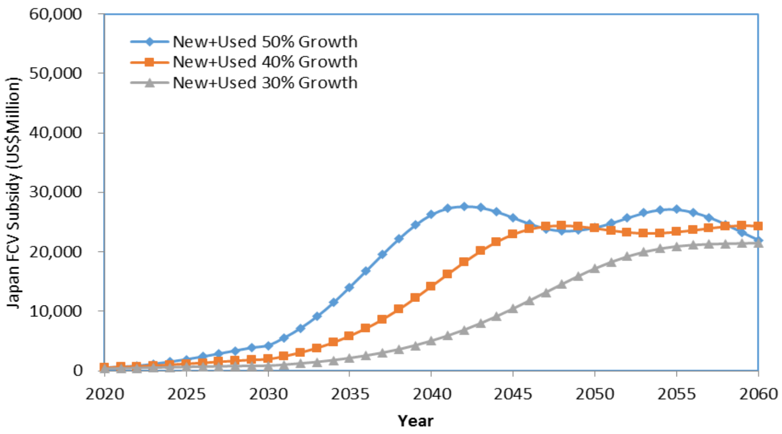
$12/kg H2





$6/kg H2





73% subsidy reduction

45% subsidy reduction

Conclusions

- At \$12/kg-H2 for new FCVs the annual subsidies in 2025 for Japan and New Zealand are \$2736 and \$2347 per FCV respectively but reduce rapidly by 2040 for the final owners of used FCVs to \$360 in Japan and \$710 in New Zealand. The lower per capita cumulative subsidy for Japan is due to the shorter FCV service life and higher depreciation.

- The total cumulative subsidy for a growth rate of 40% from 2021 peaks at \$44 billion in Japan in 2047 and at \$4.5 billion in New Zealand in 2060.

- The cost of avoiding a tonne of $CO_{2\text{-eq}}$ emissions in 2025 due to HFCV adoption at 40% growth rate is \$1906 for Japan and \$2111 for New Zealand. In 2040 the respective costs are \$1081 and \$1197.

- The nature of electricity generation in the production of hydrogen is critical to the cost of avoiding CO2 emissions. Domestically produced hydrogen in Japan increases emissions over CVs unlike New Zealand as CO2 emissions from electricity are 0.54 kg/kWh in Japan and only 0.14 kg/kWh in New Zealand.

Conclusions (cont.)

- In Japan, if hydrogen is imported from zero net carbon sources, the FCV fleet will produce less than 25% of the emissions of an EV fleet assuming the current mix of electricity generation.

- The key factors to improving the cost competitiveness of a FCV fleet and mitigating CO2 emissions are minimising the cost of electricity used in electrolysers and decreasing the capital cost of FCV vehicles.

- A 50% reduction in H2 price from $12/kg to $6/kg reduces the cumulative subsidy in Japan and New Zealand by 45% and 73% respectively.