The Impact of EV policy on the New Zealand Power System

A retro-analysis

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CHRISTCHURCH NEW ZEALAND

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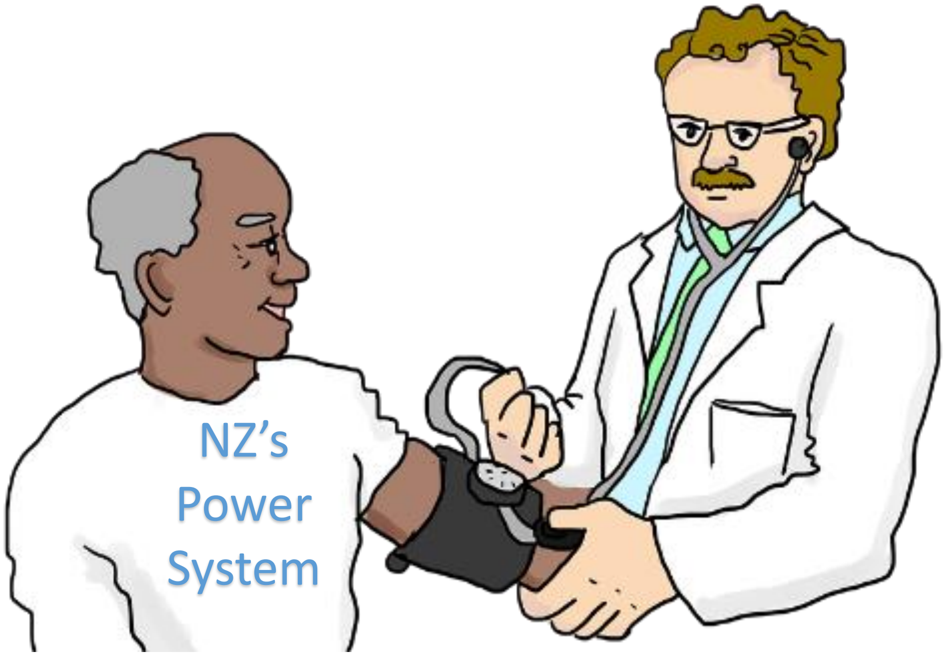
Motivation

- EVs: Future of Transportation?
- NZ EV targets and projections:
  - 64k EV's by 2021 & 40% share of EV by 2040
- NZ high share renewables, EV's seem suitable…
- However,
  - Added stress on the power system
  - Substantial investments
  - Increased emissions?



… critical to understand the impact of EV's in New Zealand

AND how they compare to other transportation alternatives

Two Stories: Norway vs. Thailand

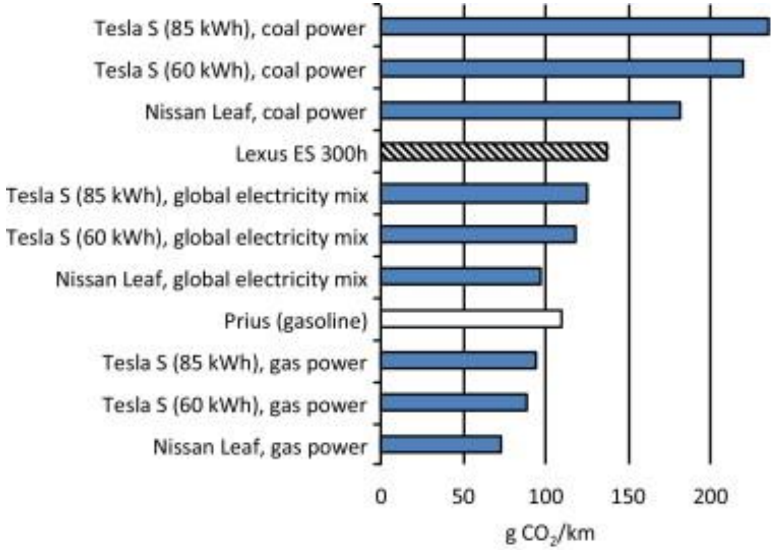
- Norway world leaders in EV adoption (2.7% total fleet)
  - Fiscal incentives (VAT & VRT)
  - High oil prices
  - Cheap (mostly renewable) electricity

	Without exemption ($)	With exemption ($)	Reduction (%)
Tesla S Performance	140,000	70,000	50
Nissan Leaf	35,000	27,000	20
Volkswagen e-up!	28,000	22,000	21

Source: Bjerkan, Nørbech and Nordtømme (2016)

- Reduced emissions (with grid capacity expansion)
  - 53% EV share - 35% reduction in emissions
- Utilities warning of higher capacity vehicle charging
  - Low share of EV's, charging can affect grid stability

- Thailand (electricity ~20% renewable)
- Modelling in for Thailand predicts higher GHG emissions with EV's.
  - **Emissions from EV's is highly dependent on grid composition.**



Source: Holtsmark and Skonhoft (2014)

As large load (EV charging) added to the grid the source of electricity may change, Simple calculation from current grid data (grid-emission factor) not adequate modelling required

Research Questions

1. What is the impact of EVs on an unmodified grid?

   Power system performance and emissions

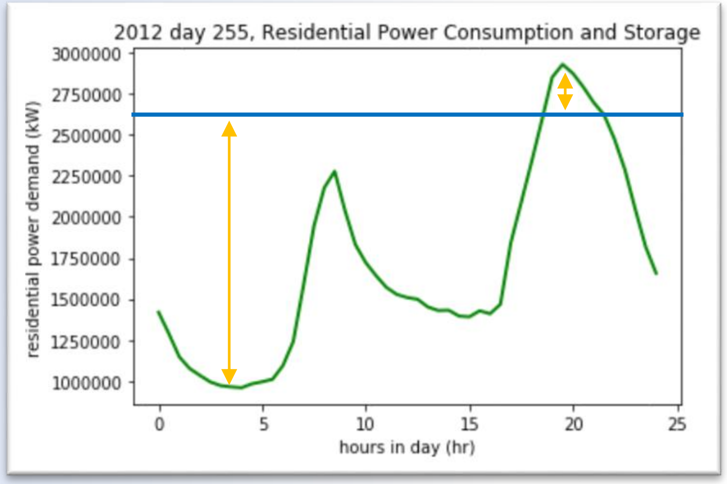
2. What is the impact of added EV with an upgraded power system?

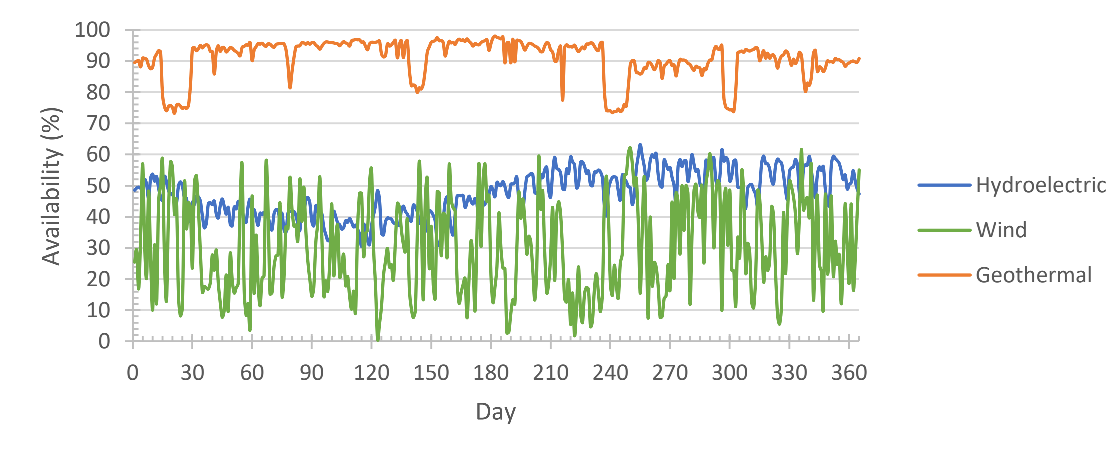
   Power system performance and emissions

3. How does this compare to other transportation strategies

Key concepts

Reserve margin & peak power





Direct and indirect emissions

Key Concepts: Retro-Analysis

- Models an energy system in a year where there is known data:
  - Transportation demand
  - Electricity sector performance (supply, demand, availability)
  - Fuel reserves
  - Emission data (Model validation)
- Impose changes
- **Avoids speculating of future demand or availability**

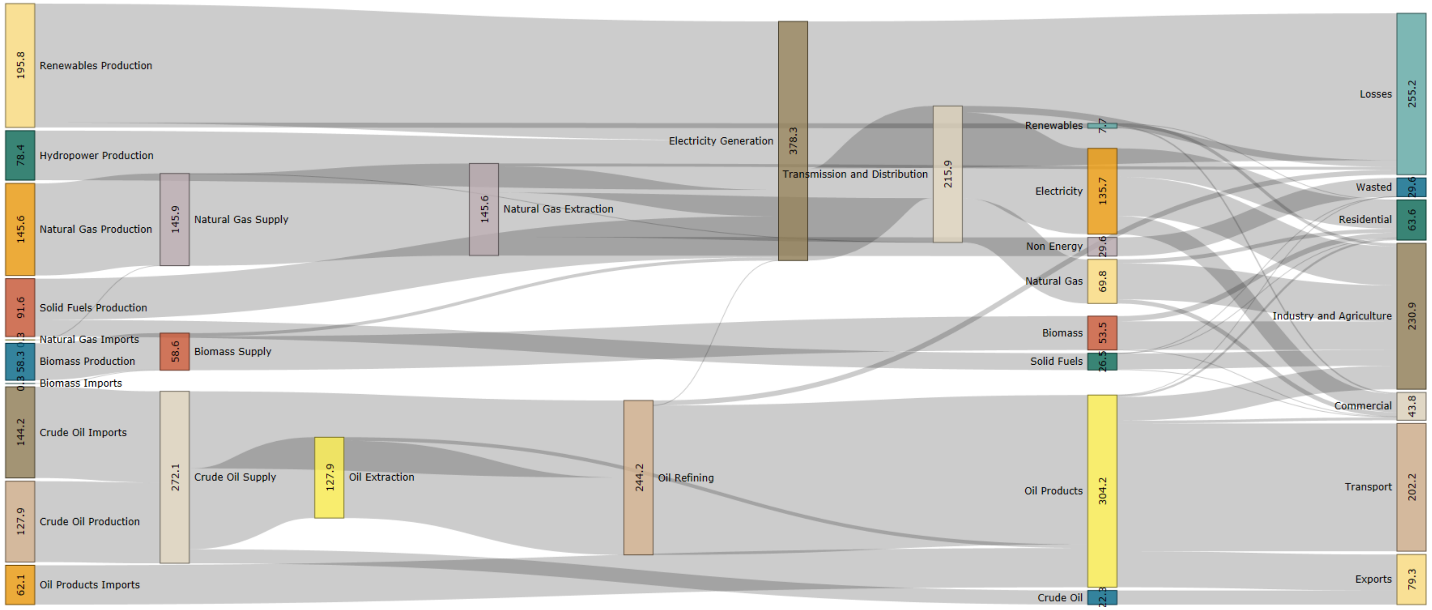
THIS ANALYSIS:
Base year is 2012 due to availability of transport activity and grid composition data.

Method

LEAP

- Energy Planning software used to simulate complex energy systems
    - Countries power and transportation systems
- Industry standard (researchers and consultants)
- Build a model of energy system given…
    - Transportation activity
    - Energy intensities
    - Power plant specifications

… uses the model to calculate the response of potential interventions on demand, transmission or supply



Sankey Diagram: NZ Energy Balance

Shows transformation from raw resource to end use

Datasets (2012 base year)	
Fuel Reserves	Energy Statistics (MBIE)
Transmission and Distribution losses	Energy Statistics (MBIE)
Power Plants (capacity and availability)	Electricity Authority
Electricity, Gas, Oil demand	Energy Balance (MBIE)
Sector electricity consumption profiles	Electricity Authority
Transportation Activity	Ministry of transport, Freight Demand Study
Performance of Power Generation Technologies and Costs	Multiple Sources, scientific literature

Method: Scenarios – Four parameters

% of EV's

EV Charging Behaviour

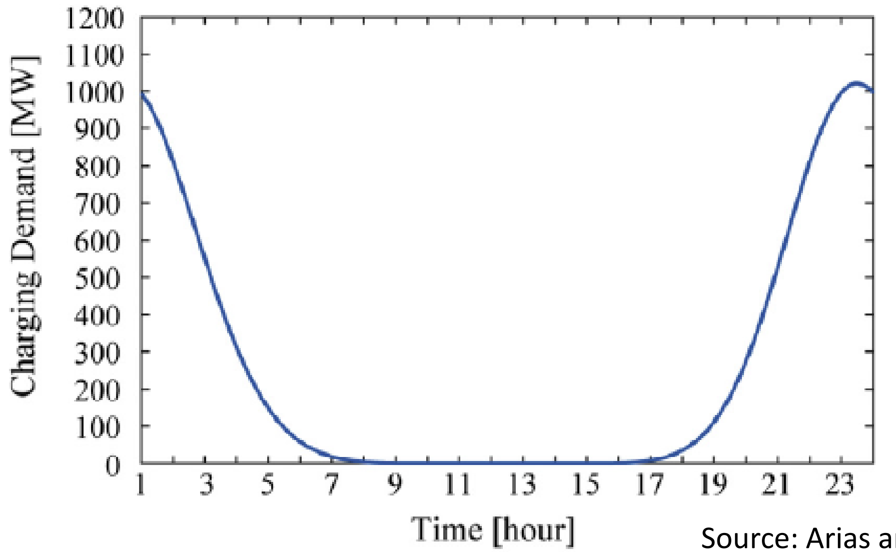
Grid Composition

Transport Alternatives

Level of ICE to EV replacement & EV charging behavior

- Two levels of ICE to EV replacement
    1. Government target 64,000 EV by 2021, (**2.3%** light vehicle fleet)
    2. MOT projects a **40%** replacement by 2040

- Two charging EV charging strategies (power system very sensitive to charging strategy)
    1. Whole fleet charging load over **8 off peak-hours** (11pm – 7am)
    2. Whole fleet charging load over **3 off peak-hours** (11pm – 2am)



Source: Arias and Bae (2016)

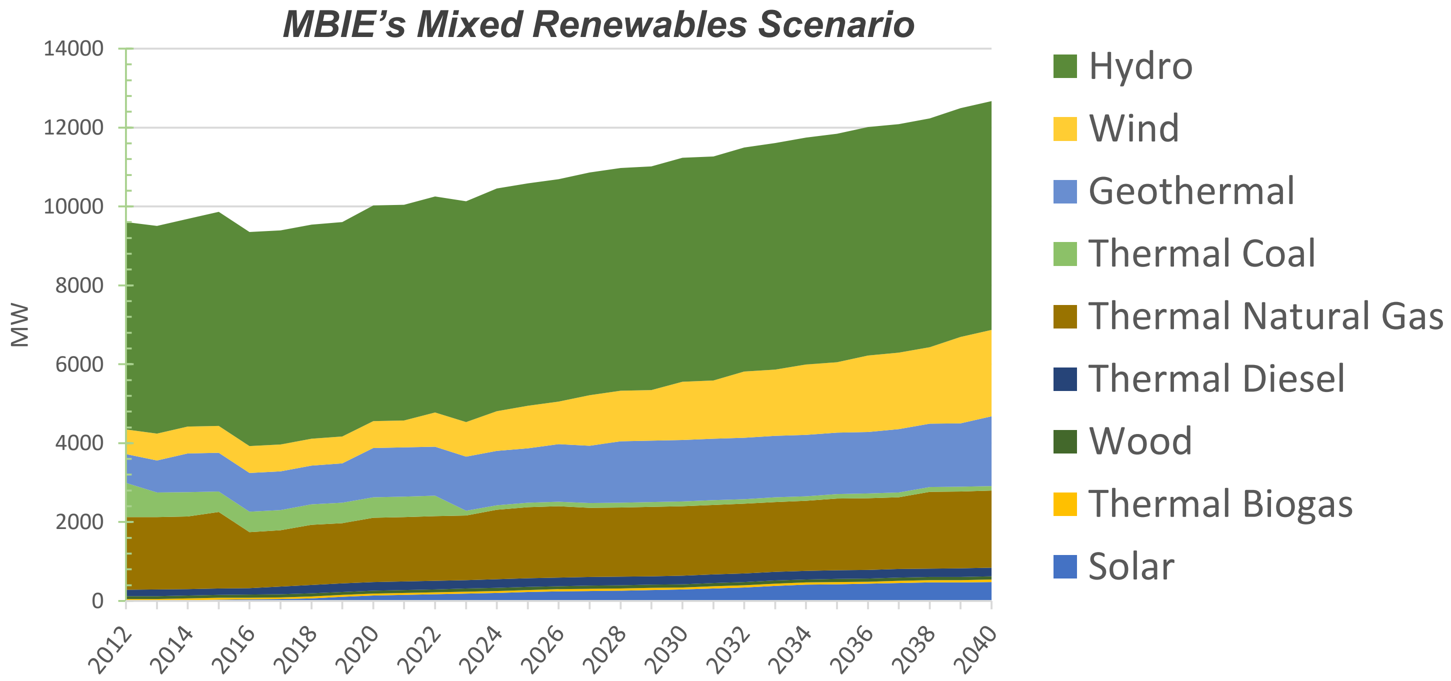
Method: Scenarios – Four parameters

- % of EV's
- EV Charging Behaviour
- **Grid Composition**
- Transport Alternatives

Modifications to power system

- Emissions from EV's are highly dependent on grid composition
  - should look proposed additions or modifications to the power system

- Mixed renewable scenario from the MBIE report was modelled
  - Believed to be the most realistic scenario.
  - Note: increase of wind power capacity which comes with its own challenges…



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% of EV's

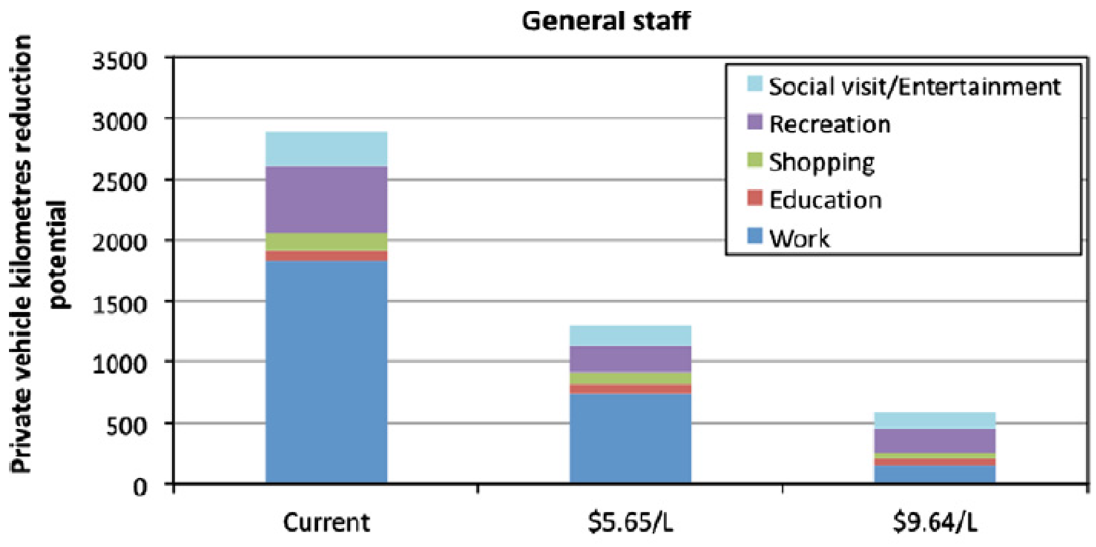
EV Charging Behaviour

Grid Composition

Transport Alternatives

Transportation Alternatives (benchmark the effects of EV's)

- 40% shift to bus transportation
- 40% VKT reduction due from behavioral change
  - Adaptive capacity: capability of transportation reduction from behavioral change while maintaining essential activites
  - With existing resources and infrastructure
  - Useful measure of resilience to energy crisis



Source: Watcharasukarn, Page and Krumdieck (2012)

Results

What is the impact of EVs on an unmodified grid?

- Current reserve margin (RM) is at a critical (-2.3%).
  - load shedding
- 64k EV (2.3%) likely tolerated

40% ICE to EV replacement

- Not facilitated by current grid (RM -7 to -13.6%)
  - With more EV's, charging behavior greater impact on RM.
- Emissions:
  - Small reductions in total (3.2%)
  - Embedded emissions from batteries
    - (estimated at 1.1 – 1.8% emissions)
  - Total ~1.7% reduction

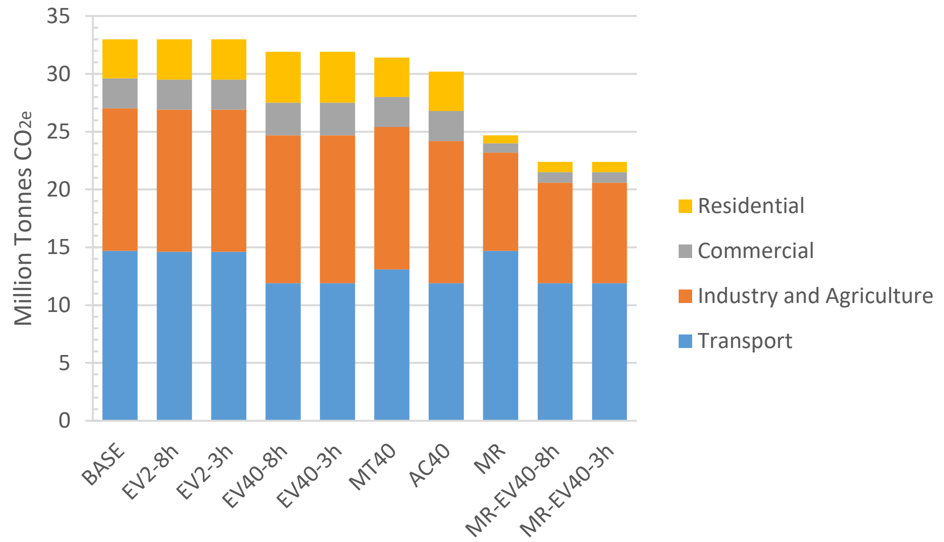
Scenario Designation	Reserve Margin (%)	Peak Power (MW)	% from BASE	Energy Demand (PJ)	% from BASE	GHG Emissions (MT CO_{2e})	% from BASE
BASE	-2.3	6,696	-	540	-	33.02	-
EV2-8h	-2.5	6,710	0.2%	539	-0.3%	32.98	-0.1%
EV2-3h	-2.5	6,710	0.2%	539	-0.3%	32.98	-0.1%
EV40-8h	-7.0	7,030	5.0%	510	-5.6%	31.97	-3.2%
EV40-3h	-13.6	7,573	13.1%	510	-5.6%	31.97	-3.2%

Results

What is the impact of added EV with an upgraded power system?

40% ICE to EV replacement

- Large increase in RM due to added capacity
  - Results sensitive to charging strategy (5.1 – 13.2%)
- Decreases in total emissions
  - Upgraded grid without EV's 25% reduction
  - With EV's 32%
  - Isolated effect of EV's = 7.2%
  - Considering battery embedded emissions -> 5.7% reduction
- Added capacity from wind
  - Not best for handling peak power to intermittency



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MR-EV40-3h	5.1	7,573	13.1%	510	-5.6%	22.36	-32.3%
MR	18.8	6,696	-	540	-	24.73	-25.1%

Results

How does this compare to other transportation strategies?

- 40% pkm shift to bus (proven technology) (5.1%) reduction in emissions
  - as effective as EV (5.1% vs. 5.7%)
  - No impacts on peak power requirements or reserve margin
  - No investments required for grid functionality.
- Feasible with existing infrastructure (Adaptive Capacity)

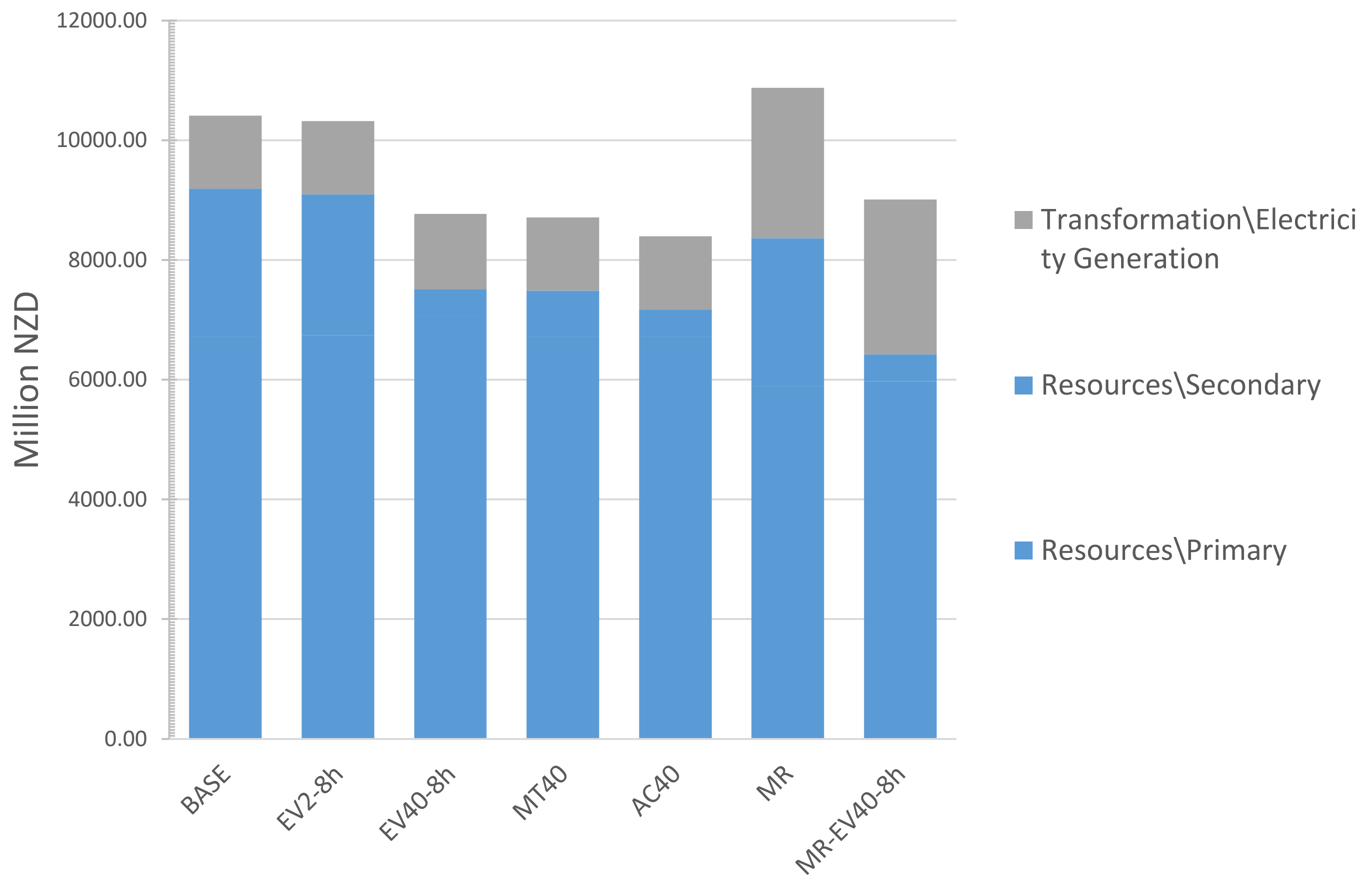
Better CO2/$ Return?

Scenario Designation	Reserve Margin (%)	Peak Power (MW)	% from BASE	Energy Demand (PJ)	% from BASE	GHG Emissions (MT CO_{2e})	% from BASE
BASE	-2.3	6,696	-	540	-	33.02	-
MT40	-2.3	6,696	-	516	-4.5%	31.35	-5.1%
AC40	-2.3	6,696	-	501	-7.4%	30.18	-8.6%
MR-EV40-8h	13.2	7,030	5.0%	510	-5.6%	22.36	-32.3% **(5.7%)**

Additional Remarks: Energy Costs

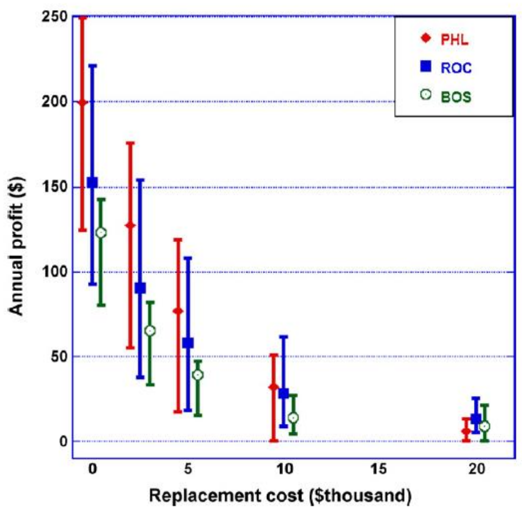
- Transport & Electricity production
  <u>Not included:</u>
  - EV vehicles & battery replacement
  - Transmission, distribution or metering infrastructure.

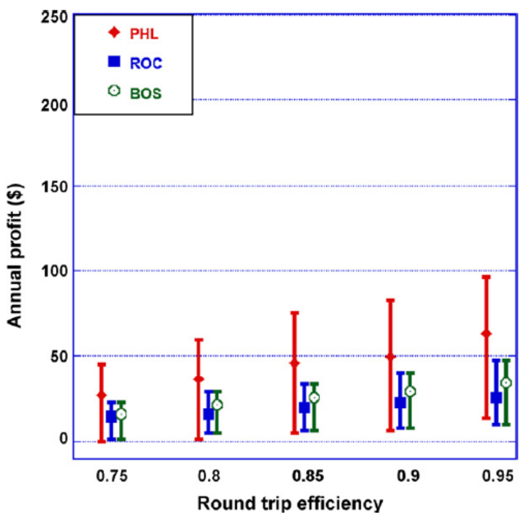
  <u>Included:</u>
  - Capital Ex for generation
  - Maintenance
  - Fuel consumption for whole system
- Cost of in-action
  - Exhaustion of reserves
  - Dependence on fuel imports
- Trends
  - Transportation alternatives:
    - Lower total cost (even with other considerations)
    - Less NR use & no increased CAPEX & OPEX
  - EV scenarios
    - With grid enhancement (GE) = increased CAPEX & OPEX
    - Without GE = similar to alternatives (non functional grid)
    - Lower NR

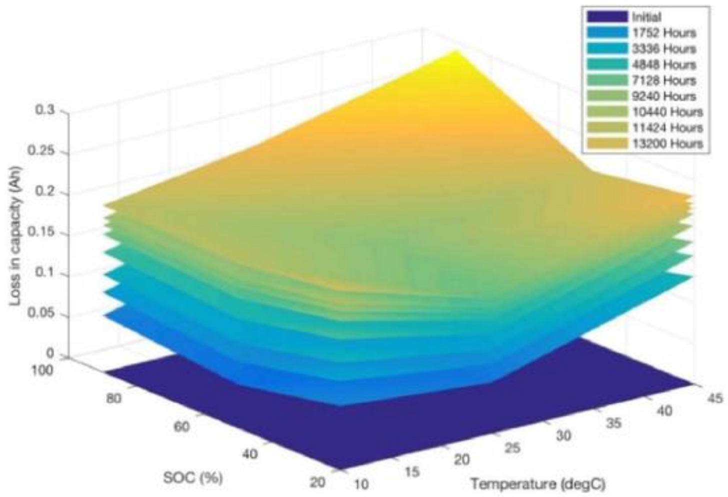


Additional Remarks: V2G or the "Smart-Grid"

- Distributed Energy Storage
  - To Improve power supply
  - To integrate of intermittent generation (wind)
  - Modelling results:
    - Improved reserve margin
    - Higher total energy expenditure
    - Higher emissions
- May play a role **BUT**…
  - Economic Feasibility
    - Max profit at high frequency trading
  - Enhanced battery degradation
  - Technical challenges
    - Comms and infrastructure
    - Availability to grid
    - Competing battery requirements (SoC)
    - Better than other storage?

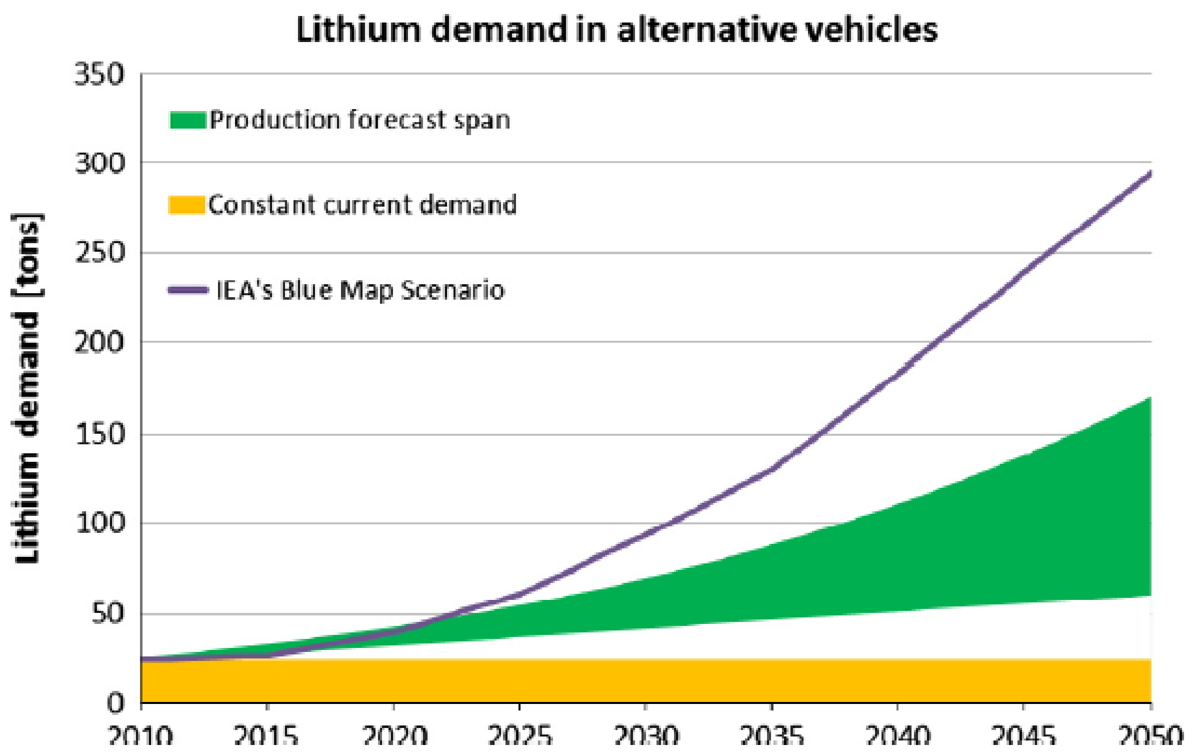






Additional Remarks: Lithium Supply

- Lithium availability
  - Is there enough Lithium?
  - Can it be produced fast enough?
    - Metals are finite resources, their deposits are limited either physically, technically, or economically.
    - Model: family of arbitrary curves, area encompass available recoverable resources and bounded by a maximum depletion rate.
  - Can it be recycled?
    - ~2%



Source: Vikstrom, Davidsson and Hook (2013)

Conclusions

- Uncoordinated charging or poor storage strategies may do substantial damage to the functionality of the grid.
- Future research should explore the costs associated with added grid and EV charging infrastructure, so the full costs of these policy decisions may be evaluated.
- Strategies involving multiple pathways (EV's, electric rail etc.) should be combined and analyzed to explore what multi-pronged solutions have the best fit for NZ.
- Economic feasibility of V2G in NZ should be assessed
- The availability and production rate of lithium is a critical factor for the uptake of EV's as Lithium is the likely battery technology for these cars.

Scenario Designation	Reserve Margin (%)	GHG Emissions (%)	GHG (%) EV effect isolated Incl. embedded
BASE	-2.3	-	-
EV40	-7.0 to -13.6	-3.2%	-1.7%
MT40	-2.3	-5.1%	-
MR-EV40	13.2 to 5.1	-32.3%	-5.7%
MR	18.8	-25.1%	-

References

- Arias, MB & Bae, S 2016, 'Electric vehicle charging demand forecasting model based on big data technologies', *Applied Energy*, vol. 183, pp. 327-39, 10.1016/j.apenergy.2016.08.080.
- Bjerkan, KY, Nørbech, TE & Nordtømme, ME 2016, 'Incentives for promoting Battery Electric Vehicle (BEV) adoption in Norway', *Transportation Research Part D: Transport and Environment*, vol. 43, pp. 169-80, https://doi.org/10.1016/j.trd.2015.12.002.
- Electricity Authority 2018, *Electricity in New Zealand*, viewed 2/19/2019, <https://www.ea.govt.nz/about-us/media-and-publications/electricity-nz/>.
- Figenbaum, E 2017, 'Perspectives on Norway's supercharged electric vehiclepolicy policy', *Environmental Innovation and Societal Transitions*, vol. 25, pp. 14-34, <<Go to ISI>://WOS:000417610800002>.
- Heaps, CG 2016, *Long-range energy alternatives planning (LEAP) system.[Software version 2018.1.20].* , MA (USA): Stockholm Environment Institute Somerville.
- Holtsmark, B & Skonhoft, A 2014, 'The Norwegian support and subsidy policy of electric cars. Should it be adopted by other countries?', *Environmental Science & Policy*, vol. 42, pp. 160-8, https://doi.org/10.1016/j.envsci.2014.06.006.
- Ministry for the Environment 2018, *New Zealand's Greenhouse Gas Inventory 1990-2016*, Wellington, New Zealand, <http://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/National%20GHG%20Inventory%20Report%201990-2016-final.pdf>.
- Ministry of Business Innovation and Employment 2012, *New Zealand's Energy Outlook Electricity Insight*, ISSN 1179-4011.
- Ministry of Transport 2017, *Transport Outlook: Future State*, Ministry of Transport, <transport.govt.nz/transportoutlook>.
- Peterson, SB, Whitacre, JF & Apt, J 2010, 'The economics of using plug-in hybrid electric vehicle battery packs for grid storage', *Journal of Power Sources*, vol. 195, no. 8, pp. 2377-84, <<Go to ISI>://WOS:000273914300032>.
- Raugei, M, Hutchinson, A & Morrey, D 2018, 'Can electric vehicles significantly reduce our dependence on non-renewable energy? Scenarios of compact vehicles in the UK as a case in point', *Journal of Cleaner Production*, vol. 201, pp. 1043-51, 10.1016/j.jclepro.2018.08.107.
- Uddin, K, Dubarry, M & Glick, MB 2018, 'The viability of vehicle-to-grid operations from a battery technology and policy perspective', *Energy Policy*, vol. 113, pp. 342-7, 10.1016/j.enpol.2017.11.015.
- Vikstrom, H, Davidsson, S & Hook, M 2013, 'Lithium availability and future production outlooks', *Applied Energy*, vol. 110, pp. 252-66, <<Go to ISI>://WOS:000321601900024>.
- Watcharasukarn, M, Page, S & Krumdieck, S 2012, 'Virtual reality simulation game approach to investigate transport adaptive capacity for peak oil planning', *Transportation Research Part A: Policy and Practice*, vol. 46, no. 2, pp. 348-67, https://doi.org/10.1016/j.tra.2011.10.003.
- Winyuchakrit, P, Sukamongkol, Y & Limmeechokchai, B 2017, 'Do Electric Vehicles Really Reduce GHG Emissions in Thailand?', *Energy Procedia*, vol. 138, pp. 348-53, https://doi.org/10.1016/j.egypro.2017.10.137.

Thank you!

Questions?

Results for all Scenarios

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