From Electric Cars to Home Energy Management

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Outline

1. EV History and Technology
2. REV Project at UWA
3. EV Trials in Western Australia
4. EVs, Environment, and Home Energy Systems
1. EV History and Technology

Previous Waves of Electric Cars

1900 Lohner-Porsche wheel-hub motors
1975 BMW LS Electric
Conspiracy Theory
1996-99 General Motors EV1
What can I buy in Australia?

Nissan Leaf 2012  
Mitsubishi Outlander 2014  
Audi A3 e-tron 2016

BMW i3 2014  
Porsche Cayenne 2014  
Porsche Panamera 2014

Tesla Model S 2015  
Tesla Model X 2017  
BMW i8 2015

Why Electric Vehicles?

Pros
- Zero emissions if charged from renewables
- Silent at low speeds
- Significantly cheaper running cost
- Significantly cheaper servicing cost
- No *(immediate)* infrastructure required

Cons
- Limited range (~150km) in combination with longer recharge time (~20 min. at DC charger)
  - Sufficient for over 90% of drives: daily avg. 39 km in Perth
  - Petrol range extenders available (plug-in hybrid)
- Higher purchase price (but lower costs later)
Battery Electric Vehicles (EV)

Advantages
- Completely emission free if charged from renewables
- Very efficient (no excess heat)
  Cheap running costs ~0.15kWh/km
  ≈ 3.6ct/km day-tariff or 1.8ct/km at night
  Petrol car [8l, $1.50] → 12ct/km → factor 7.5 (w/o tax 5.6)
- Reduced servicing cost
- Charge from home with clean energy: solar, wind

Disadvantages
- Higher purchase price than petrol car (initially)
- Limited range (will go away) in combination with
- Long charging time (already gone)

Plug-in Hybrids (PHEV)

Advantage
- Drive on battery for short distances
- Drive long distances on petrol
- Overall low fuel consumption

Disadvantages
- Expensive (range extender or dual drive train)
- Small electric-only range
- Usually no fast-charging
**EV and PHEV Range**

<table>
<thead>
<tr>
<th>Model</th>
<th>Petrol range ext.</th>
<th>Battery</th>
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<tr>
<td>BMW i8</td>
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<td>GM Volt</td>
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<td>REV Getz</td>
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<td>REV Lotus</td>
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<td>Mitsubishi iMiEV</td>
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<td>EV Trial Focus</td>
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<td>BMW i3</td>
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<td>Mercedes B-Electric</td>
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<td>Tesla Model S</td>
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**Hydrogen Fuel Cell**

*What happened to hydrogen fuel cell cars??*

- Meant to be the next car technology 20 years ago …
- … and are still 20 years away … or may never come

**Advantages**

- Convenient filling
  
  *once hydrogen infrastructure is in place*

**Disadvantages**

- Requires expensive hydrogen stations
- Expensive fuel cells in cars
- Hydrogen is explosive!
- Hydrogen expensive to produce and transport
EV Charging

Level 1 (2.4kW)
Slow charging at home

Level 2 (7.7–21kW)
Medium-fast charging in parking lots and shopping centres

Fast-DC (50–450kW)
Fast charging at service stations

Comparison
Max: 14.5kW

EV Charging Standards

AC Charging

US and Japan
- IEC 62196-2 Type 1 (SAE J1772)
- Single Phase, 120-240V, max 70A, 16.8kW

Europe
- IEC 62196-2 Type 2 (“Mennekes”)
- Three Phase, 230/690V, max 63A, 43kW

China
- Earlier version of European IEC Type 2
- Three Phase
EV Charging Standards

DC Charging

Japan: • ChaDeMo

Europe: • Combo Type 2

US: • Combo Type 1
• Tesla Mennekes

Battery Swapping

1899 Battery swapping station in France
1970 Electric van, Hannover, Germany
2010 A Better Place, Israel, now bankrupt

Technically feasible, but Will not work because of cost & vehicle design reasons
Inductive Charging

- Convenience
- Energy loss
- Magnetic field

Clean Energy

EVs are only as clean as the energy you put in!

1. PV on car
   - Not enough area

2. Wind turbine on car
   - No, no, no !!

3. PV/Wind turbine directly connected to charging station
   - Not always utilized
   - Not always usable

4. Grid-connected PV/Wind turbine on house roof (ideally with local storage)

250Wp panel = 1kWh/day = 6km per day

Source: REUK, GreenPatentBlog, Toyota
Ideal House – Power Generation

1.5kWp Photovoltaic System
6kWh/day ≈ 40km/day

EV Initiatives

South Australia:
30% EV/PHEV in Gov. fleet by 2019 (buy 2,000 cars)

South Korea:
30% of all new cars zero-emission from 2025

Norway:
100% of all new cars zero-emission from 2025

Netherlands:
100% of all new cars zero-emission from 2025

India:
100% of all new cars zero-emission from 2030
2. REV at UWA

2008 REV Eco

Car: 2008 Hyundai Getz parts cost ~$15,000
Motor: Advanced DC, 28kW
Controller: Curtis 1231C, 500A
Instrument.: EyeBot M6 with GPS fuel gauge driver
Batteries: 45 x 90Ah = 13kWh, 144V, 135kg
Total weight: 1160kg (petrol), 1160kg (EV)
Range: 80km (road tested)
Charging: 6h
Top speed: 125km/h
2009/10 REV Racer

Car: 2002 Lotus Elise S2
parts cost ~$45,000

Motor: UQM, Powerphase 75kW
regenerative braking

Controller: UQM, DD45-400L, 400A

Instrument.: Automotive PC (XP)
fuel gauge driver

Batteries: 83 x 60Ah = 16kWh
266V, 191kg

Total weight: 780kg (petrol), 936kg (EV)

Range: 100km

Charging : 6h

Top Speed: 200km/h estimate

2010&2013 REV Formula SAE-E

SAE introduced Hybrid League in 2008, Electric League in 2010
Annual SAE event in Melbourne in Dec.

Sponsor

Swan Energy
3. WA Electric Vehicle Trials

1st Australian EV Trial: 2010-13
1st Australian Level-2 Network: 2010-15

ARC Linkage Project on EV Charging Behaviour

Charging Network in Perth
- 23 Level-2 (Type 2) charging bays
- 1 fast-DC station
- How much infrastructure will be required in future?
- Where do EVs charge?
- When do EVs charge?
- How to shift load?
Trial Results

Driving and Charging
- 82% of all charging events happen at only two different locations per vehicle (89% at top three locations)

Charging
- Results: Peak charging time is 8am-10am with a lower base load from 10am-8pm and very little load during the night
Trial Results

Charging
- Charging stations are often occupied for a full working day, while charging only requires a few hours

5. EVs. Environment, and Home Energy Systems
Environmental and Health

14% of all CO₂ Emissions are from Transport

- EVs will improve air quality and public health in metro areas

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Beyond Cars

Why stop with clean cars?
→ Build green houses!!

- After 10 years in a car (85% capacity), batteries can be re-purposed as Second Life batteries for home energy storage
- After another 10-20 years, batteries can be fully recycled

Plus-Energy House,
Berlin, 2012
Could we have a power generation that is 100% from renewables?

**Problem:** Energy Storage
Energy is also required when there is no sun or wind

**What is the solution?**

- Hydro Dams (Pump water up the hill, see Canada, Scandinavia)
- Flywheels (Mechanical energy storage)
- Generate H\(_2\) and store for later use
- Use large battery banks (1MWh in a sea container, e.g. Alkimos), or smaller ones, e.g. 10kWh for home energy usage
Vehicle-to-Grid vs Home-to-Grid

V2G Idea: Use huge number of EVs as storage to
- Meet peak power demands as spinning reserve
- Allow more fluctuating renewables on grid

V2G Problems
- Required infrastructure (2-way charging stations + lots of them: 100x more)
- Inconvenience for EV users
- Technically feasible, but:
  - Currently limited battery lifetime: $10,000 / 2,000 cycles = $5 “battery wear” per charge in addition to ~$2 energy borrowed (daytime 10kWh)

Better: Separate home energy storage

Automated Demand-Response

Worst Possible EV Scenario
aka “OEM’s Nightmare”
Automated Demand-Response

BMW ChargeForward Solution
Great for all parties: utility, EV customer, OEM

1. Request power reduction

2. Inform users via app and give chance to opt-out

3. Delay charging for participating EVs

Source: Simon Ellgas, BMW 2015

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Renewable Energy Vehicle Project (REV)  http://REVproject.com