BEYOND ONE BILLION ELECTRIC VEHICLES BY 2050

STRATEGIES FOR LARGE-SCALE EV DEPLOYMENT

CHRISTINA CHANG – HEJC – 3/20/2017

PRESENTATION STRUCTURE

CURRENT EV INDUSTRY

SUMMARY & OUTLOOK

CARBON CONTEXT

CHALLENGES & SOLUTIONS

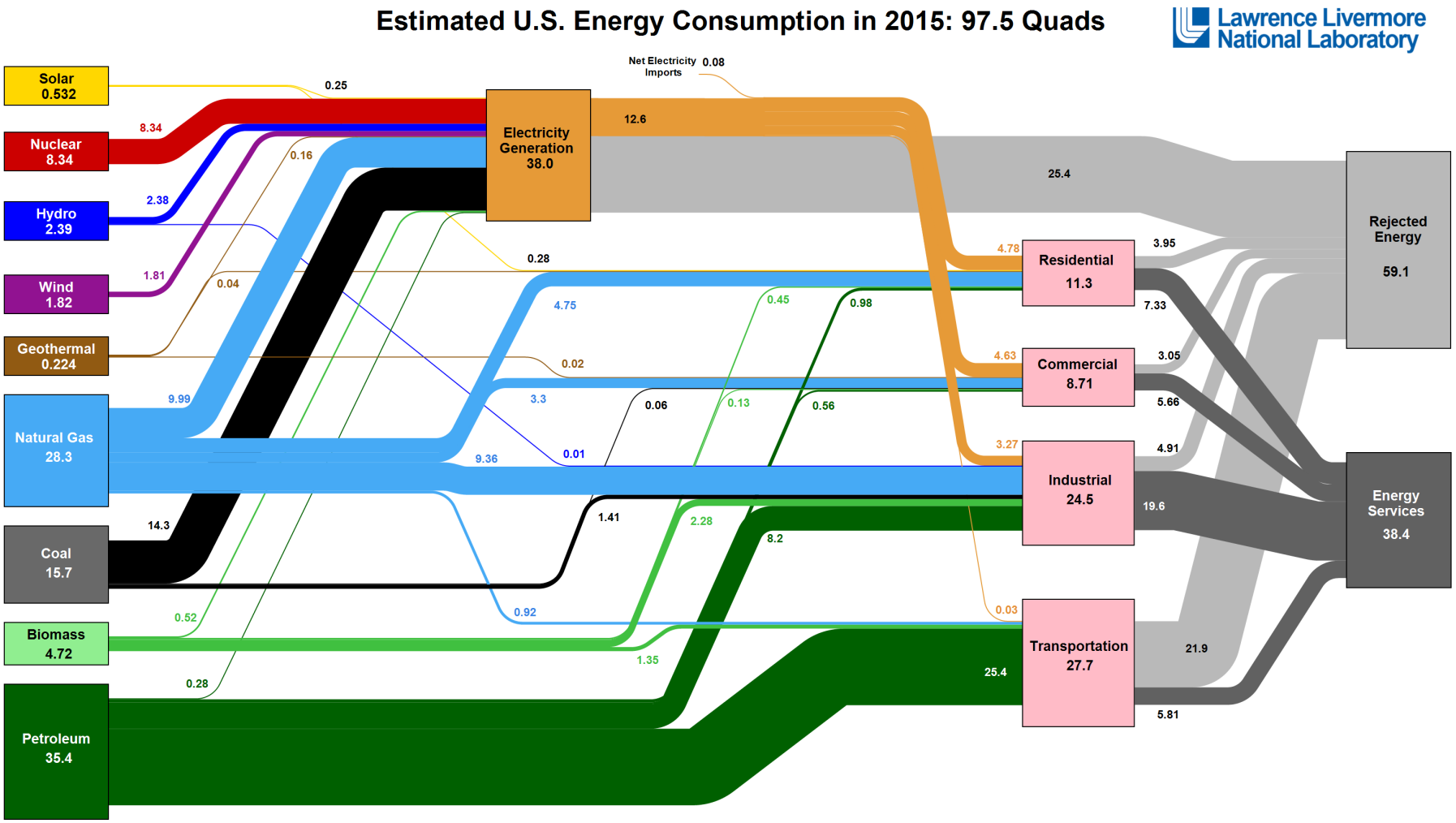
- Addressing the high cost of PEVs
- Addressing the limited charging infrastructure
- Addressing consumer misconceptions

1. Context

How the U.S. can achieve an 83% reduction in CO_2 emissions relative to 2005 by 2050?

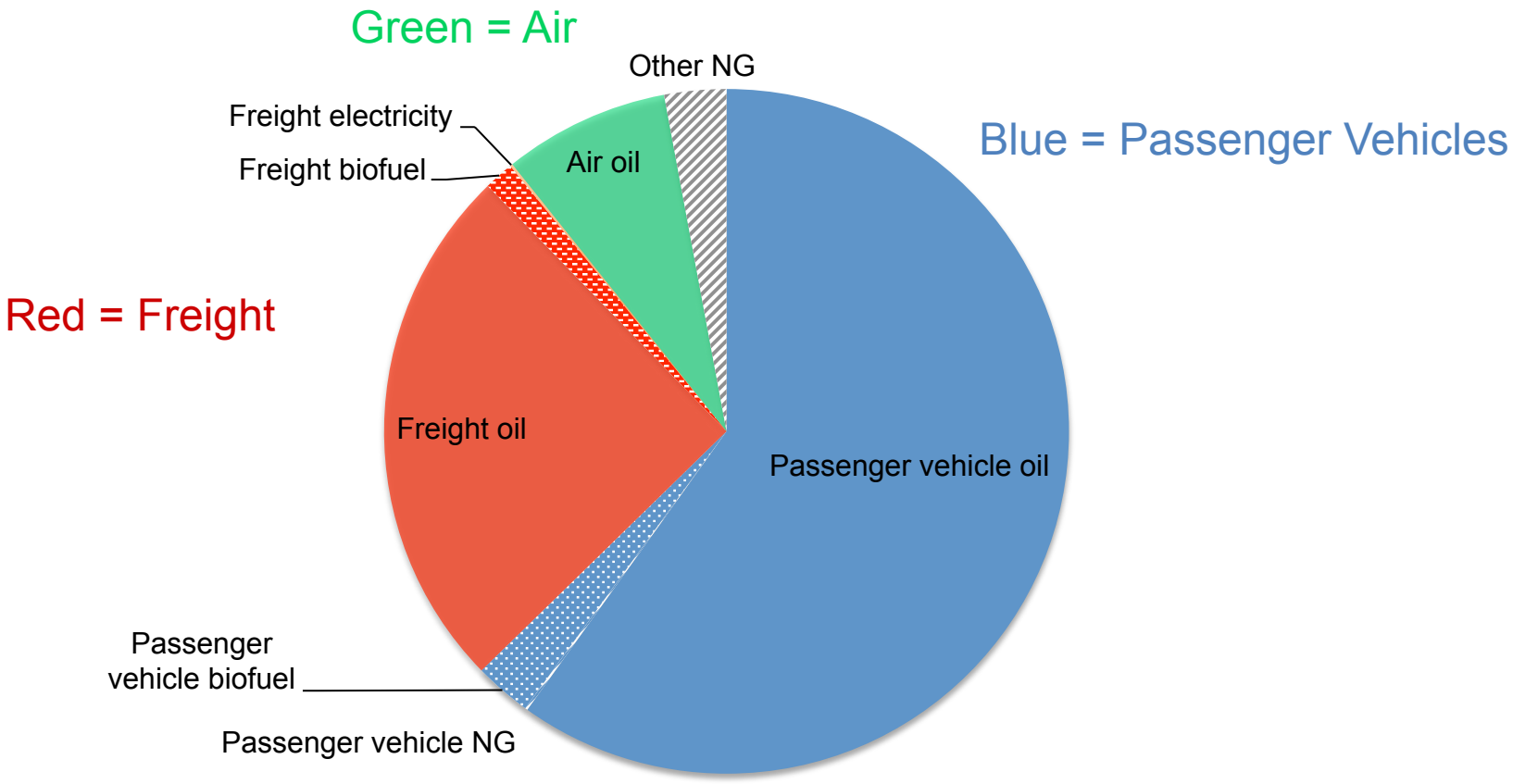
Which CO_2 polluter is hardest to mitigate?

Transportation is 26% efficient and is 92% oil-powered.



Source: LLNL March, 2016. Data is based on DOE/EIA MER (2015). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent Rounding. LLNL-MI-410527

Passenger vehicles are the largest piece of the transportation pie and the easiest to electrify



Caveat: We should switch to public transportation as much as possible eventually, but this cannot all be built by 2050.

How much can we decrease energy use by cars?

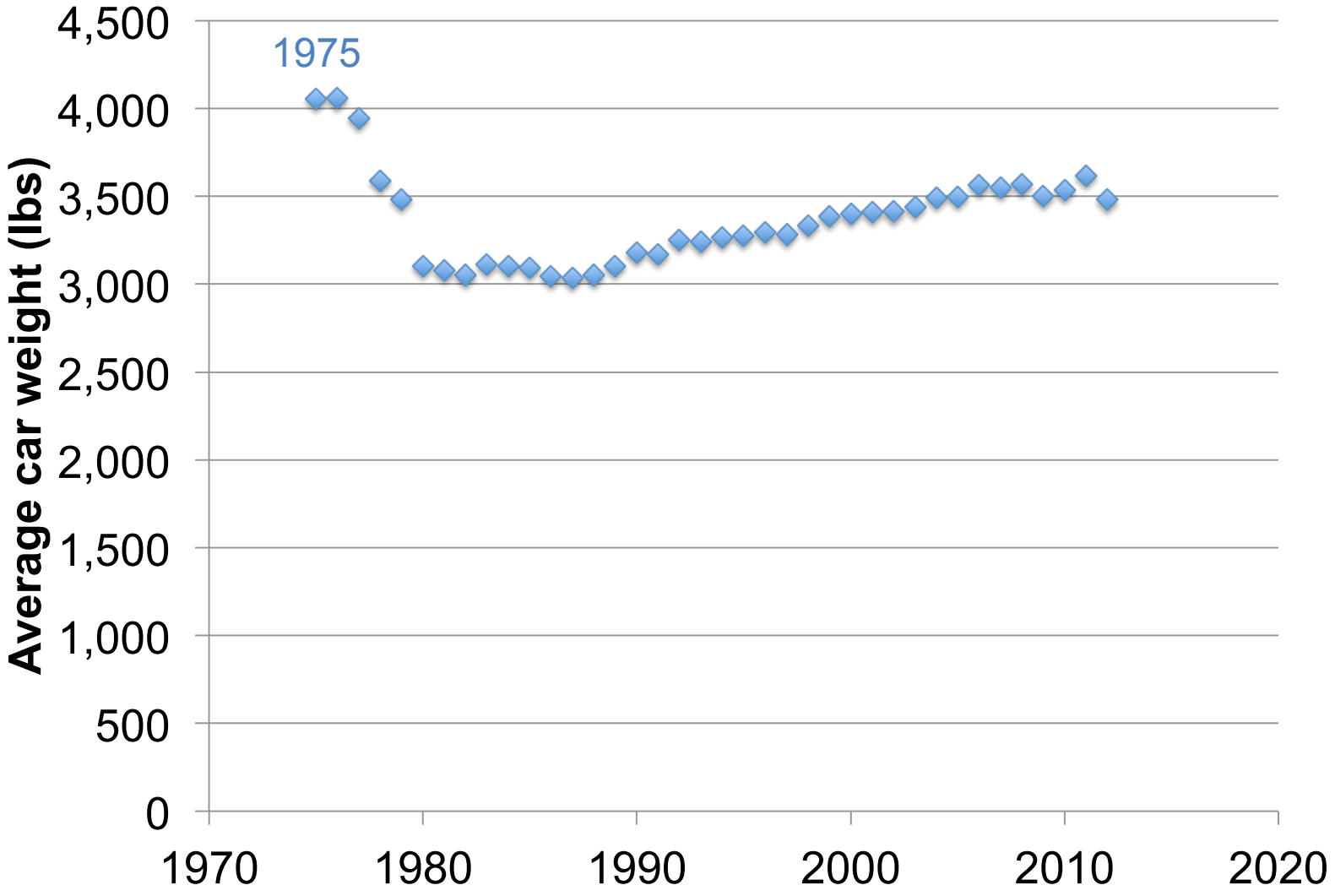
$$\text{Power} = \frac{1}{2}\frac{m_c v^3}{d} + \frac{1}{2}\rho A v^3$$

distance driven before braking

air density

Term 1 dominates for city driving (<0.47 mi before braking).
We must reduce m_c and v.

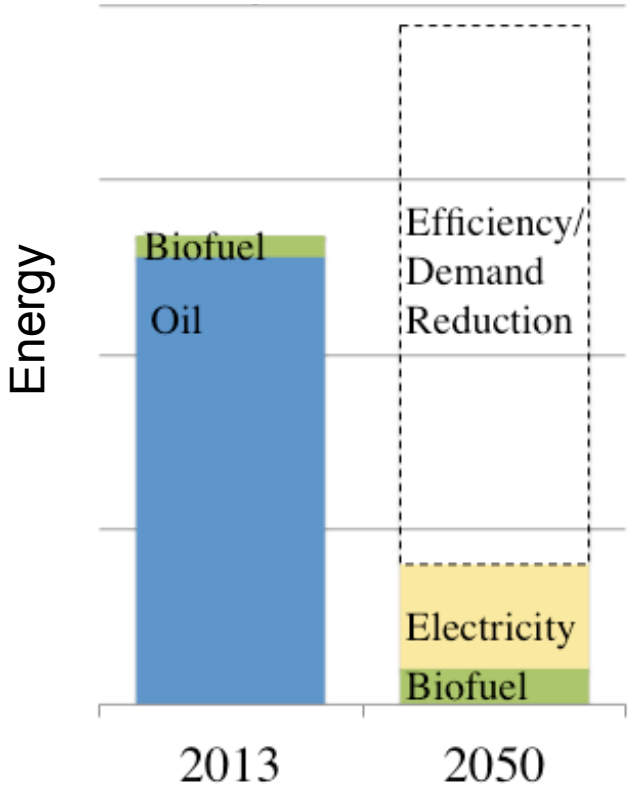
How much can we decrease the mass of cars?



How many electric vehicles will we need, and how much energy will they require?

Assumptions:

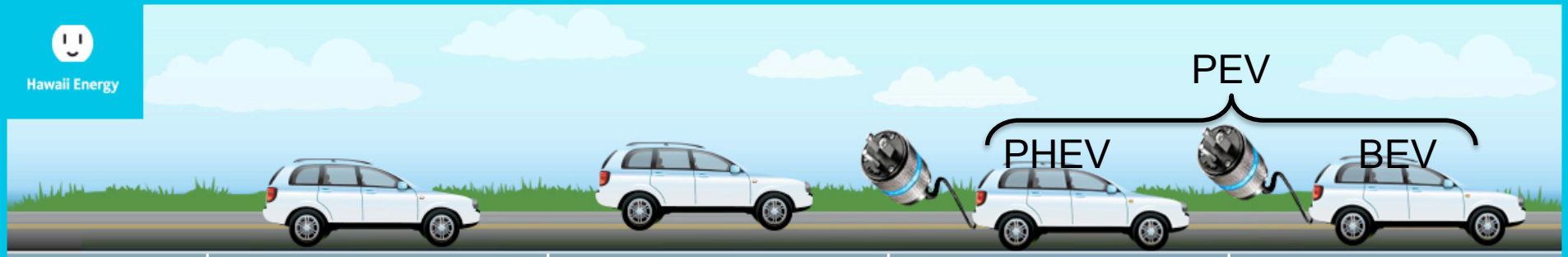
- BAU: car-miles traveled increases 42% by 2050
- All cars are 3,000 lbs
- 10% reduction from BAU due to ride sharing and public transportation
- ICE is 18% efficient (true today)
- Electric motor is 80% efficient (true today)



US:	256M ICE cars	360M EVs
World:	809M ICE cars	> 1B EVs

2. EV Industry

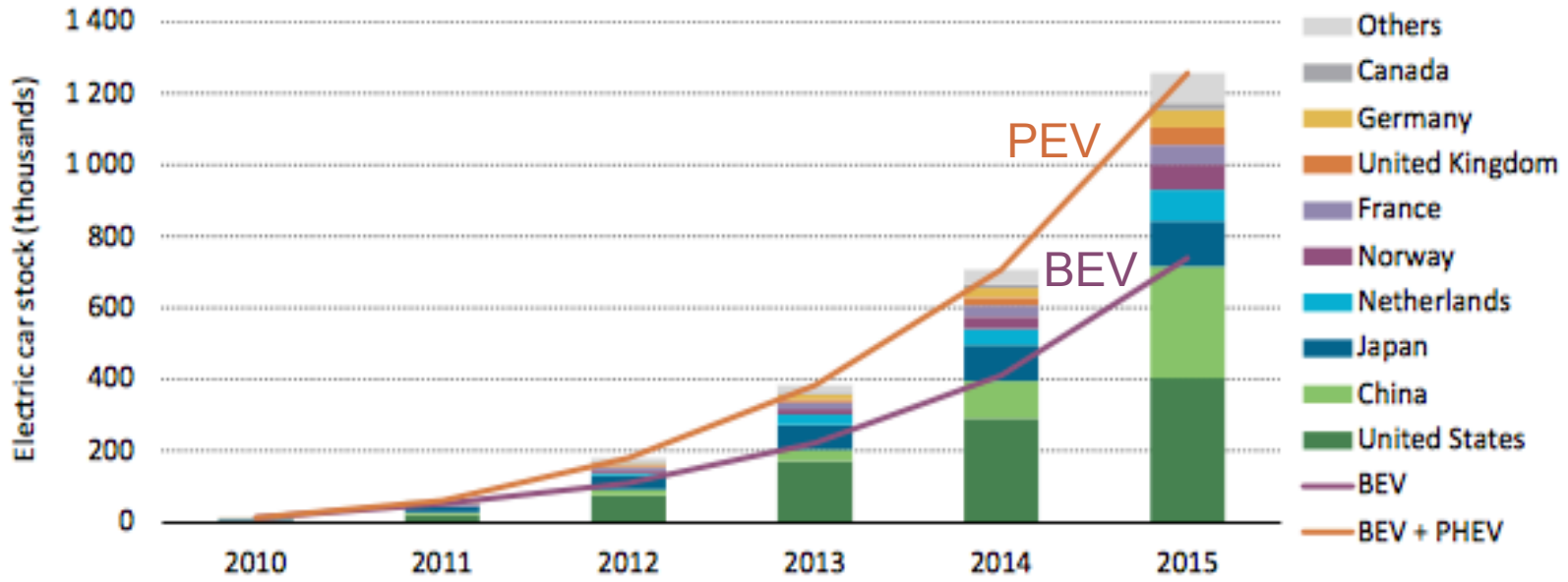
Hawaii Energy



	CONVENTIONAL	HYBRID	PLUG-IN HYBRID	ALL -ELECTRIC
Sources of Energy				
Consumption				
Emissions				
Examples		Toyota Prius (C, V) Ford C-Max, Fusion Hybrid Hyundai Sonata Hybrid Volkswagen Jetta Hybrid Lexus RX 450h Infinity Q70 Hybrid	Ford C-Max, Fusion Energi Honda Accord PHV Chevy Volt Toyota Prius PHV Cadillac ELR Porsche Panamera S E-Hybrid	Nissan Leaf Tesla Model S BMW i3 Mitsubishi MiEV Chevrolet Spark EV

The EV Market is growing ever more rapidly

Figure 1 • Evolution of the global electric car stock, 2010-15



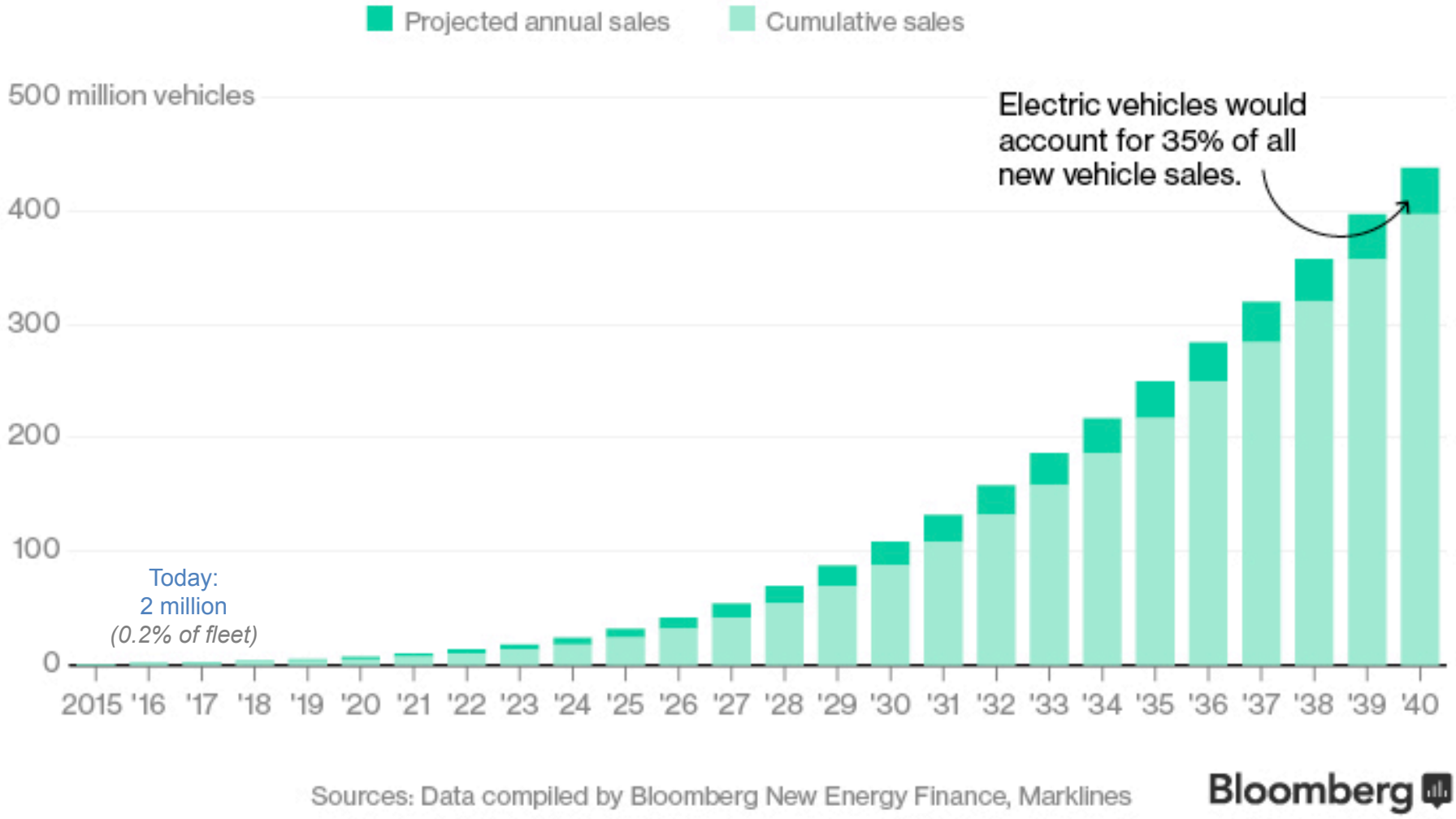
Note: the EV stock shown here is primarily estimated on the basis of cumulative sales since 2005.

Sources: IEA analysis based on EVI country submissions, complemented by EAFO (2016), IHS Polk (2014), MarkLines (2016), ACEA (2016a), EEA (2015) and IA-HEV (2015).

Key point • The electric car stock has been growing since 2010, with a BEV uptake slightly ahead of PHEV uptake. 80% of the electric cars on road worldwide are located in the United States, China, Japan, the Netherlands and Norway.

Source: https://www.iea.org/publications/freepublications/publication/Global_EV_Outlook_2016.pdf

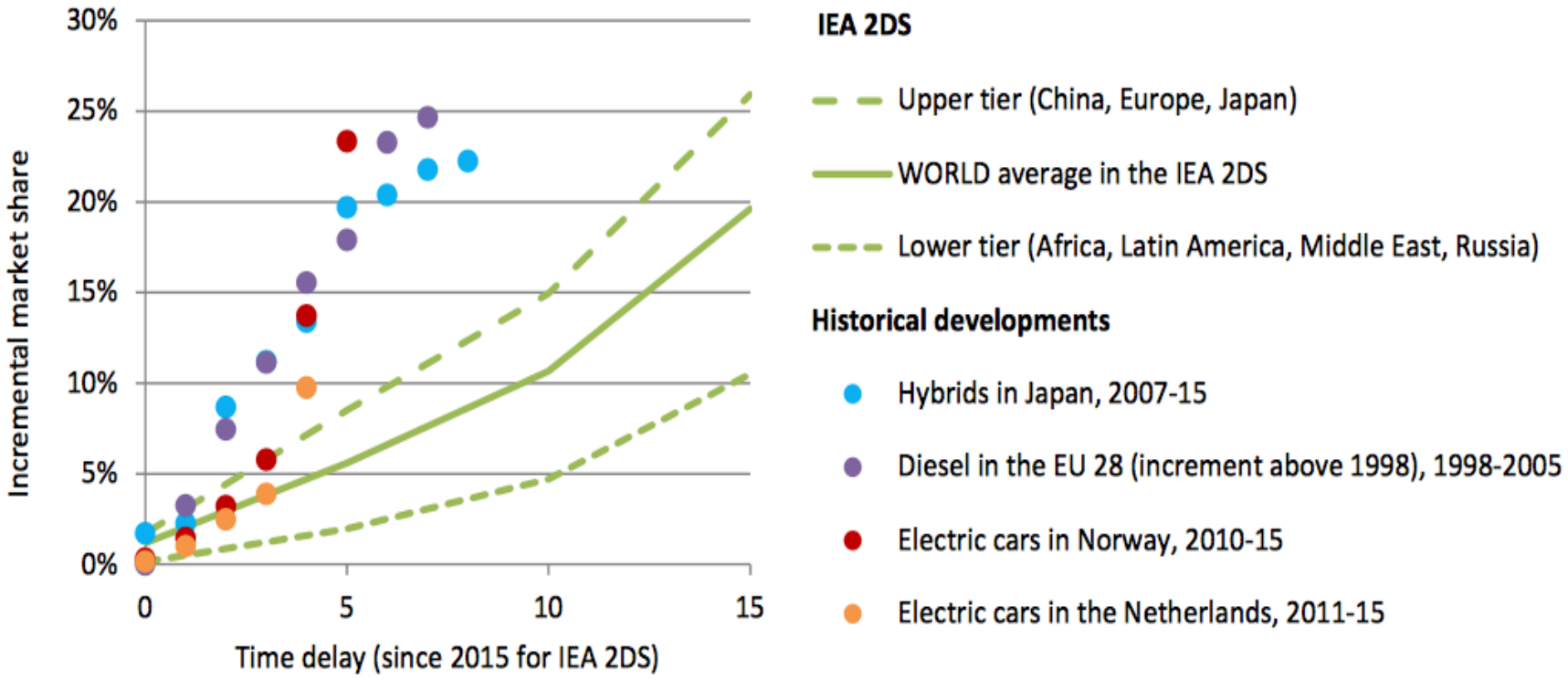
...Still, 1 billion EVs by 2050 would be off-the-charts



Some countries are on track for fast adoption

Japan, Norway, The Netherlands

Figure 10 • Market penetration for electric cars needed to meet the IEA 2DS target compared with a selection of significant historical transformations in powertrain technologies



Sources: IEA analysis based on IEA (2016b), ACEA (2016b), Eurostat (2016), IHS Polk (2014) and MarkLines (2015).

3. Challenges & Solutions

https://www.pinterest.com/stacey_ault13/cars/

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How expensive are PEVs?

2017 BMW i3

$43,395

81-114 miles

2017 Chevy Bolt

$37,495

238 miles

2017 Nissan Leaf

$31,545

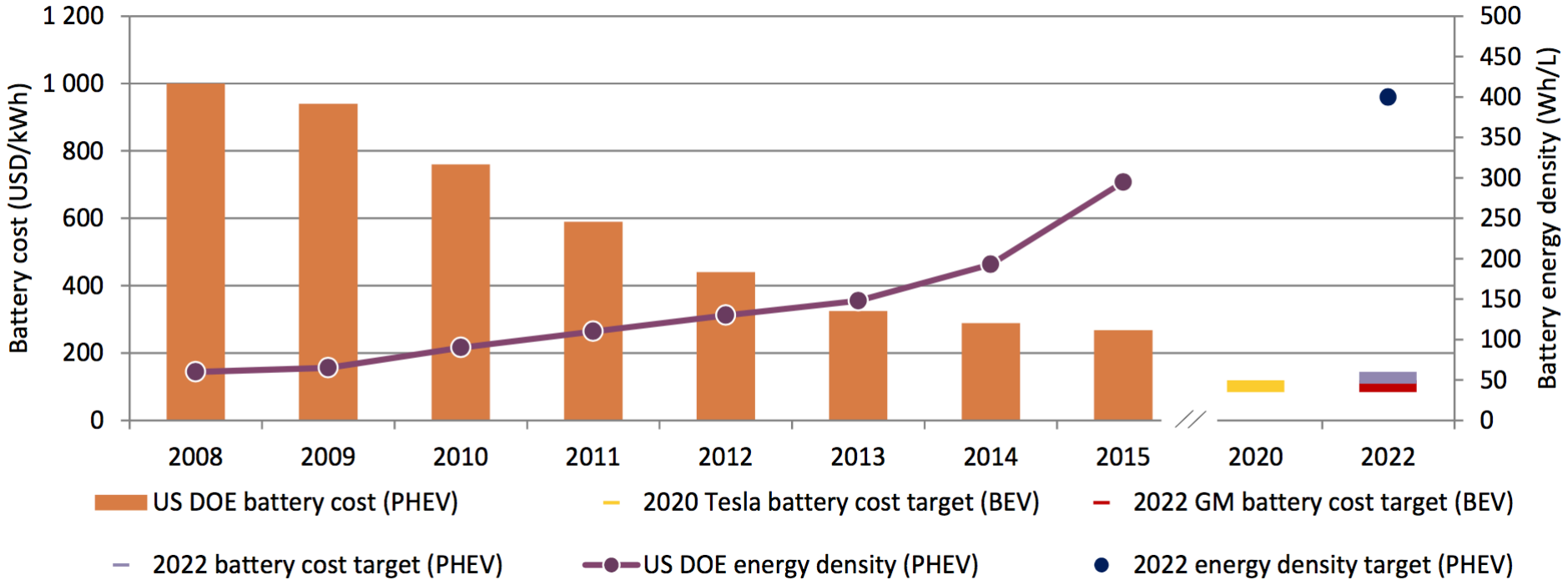
107 miles

2017 Tesla Model S

$69,200 to $135,700

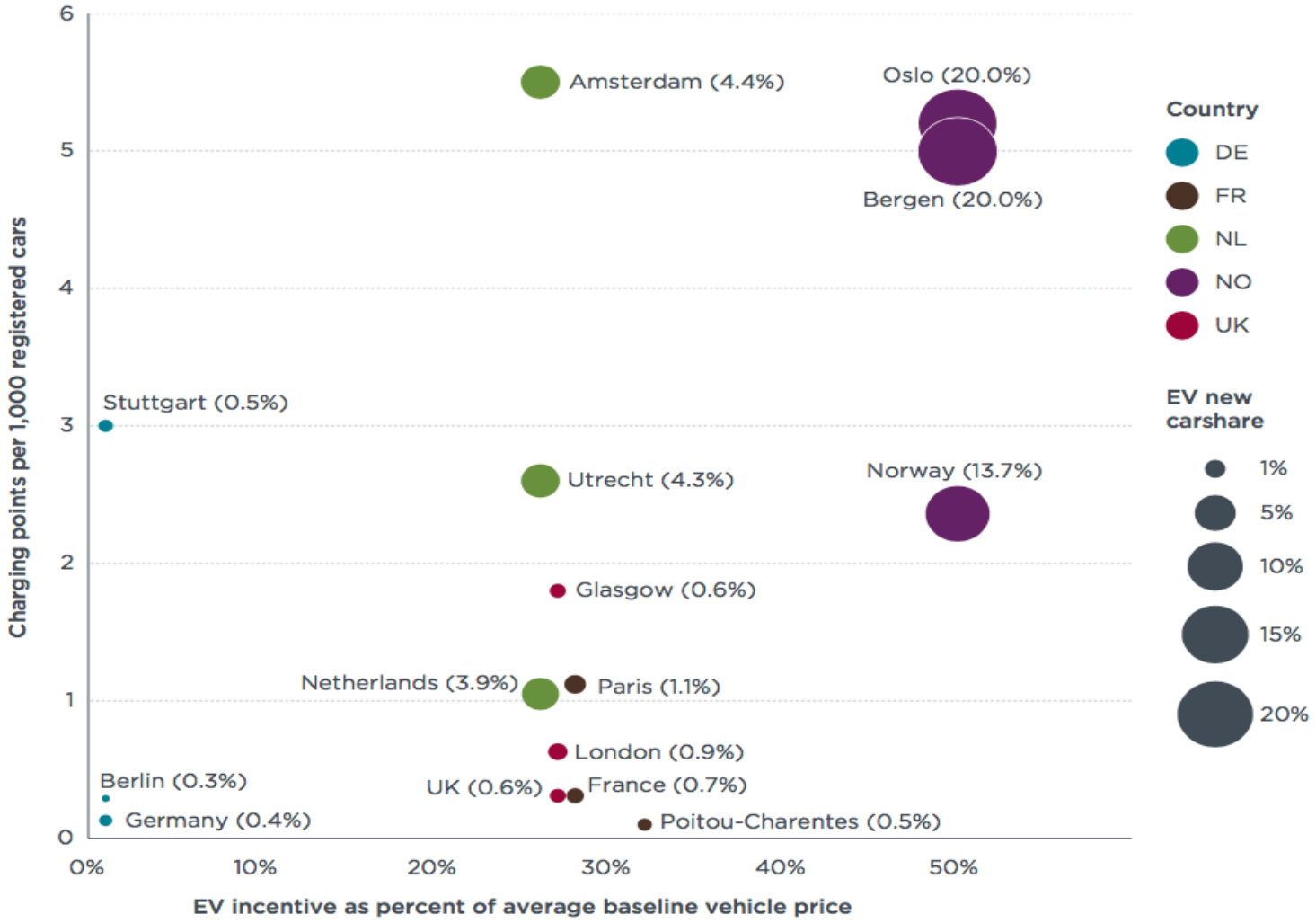
210-315 miles

How expensive are PEVs?



Sources: https://www.iea.org/publications/freepublications/publication/Global_EV_Outlook_2016.pdf, US DOE (2015 and 2016) for PHEV battery cost and energy density estimates; EV Obsession (2015); and HybridCARS (2015)

Increasing fiscal incentives increases EV share of new vehicles



Source: http://www.theicct.org/comparison-ev-policies-europe-2016

NORWAY CASE STUDY:

EVs already have 5% market share in Norway. In 2016, 37% of new cars sold were EVs. How has Norway achieved this high EV penetration?

BMW i3

#2

selling car last month

Policies

Tax & Toll Exemption

Bus Lanes & Free Parking

7,632 Charging points

Home charger incentive

Norway

Population 5.2 million
High GDP per capita
Electricity mostly hydropower

<u>Similar to the USA:</u>

- Sparsely populated
- Approximately 80% people live in urban areas
- 90% of passenger-miles traveled by car

Norway

Population 5.2 million
High GDP per capita
Electricity mostly hydropower

Of new vehicles:
12.6% are BEVs
1.2% are PHEVs

Of all existing vehicles:
5% are EVs

Fast DC charging stations in Nebbenes, Norway

Electric car rally in Geiranger, Norway

Electric car rally in Geiranger, Norway

Norway government fleets transition to PEVs

Police vehicles

Public buses

Private cabs

Public taxis

Oslo

Highest EV density of any capital
Goal: climate neutral by 2050
Pop: 650,733
Charging points: 1,820
Registered EVs: 12,000

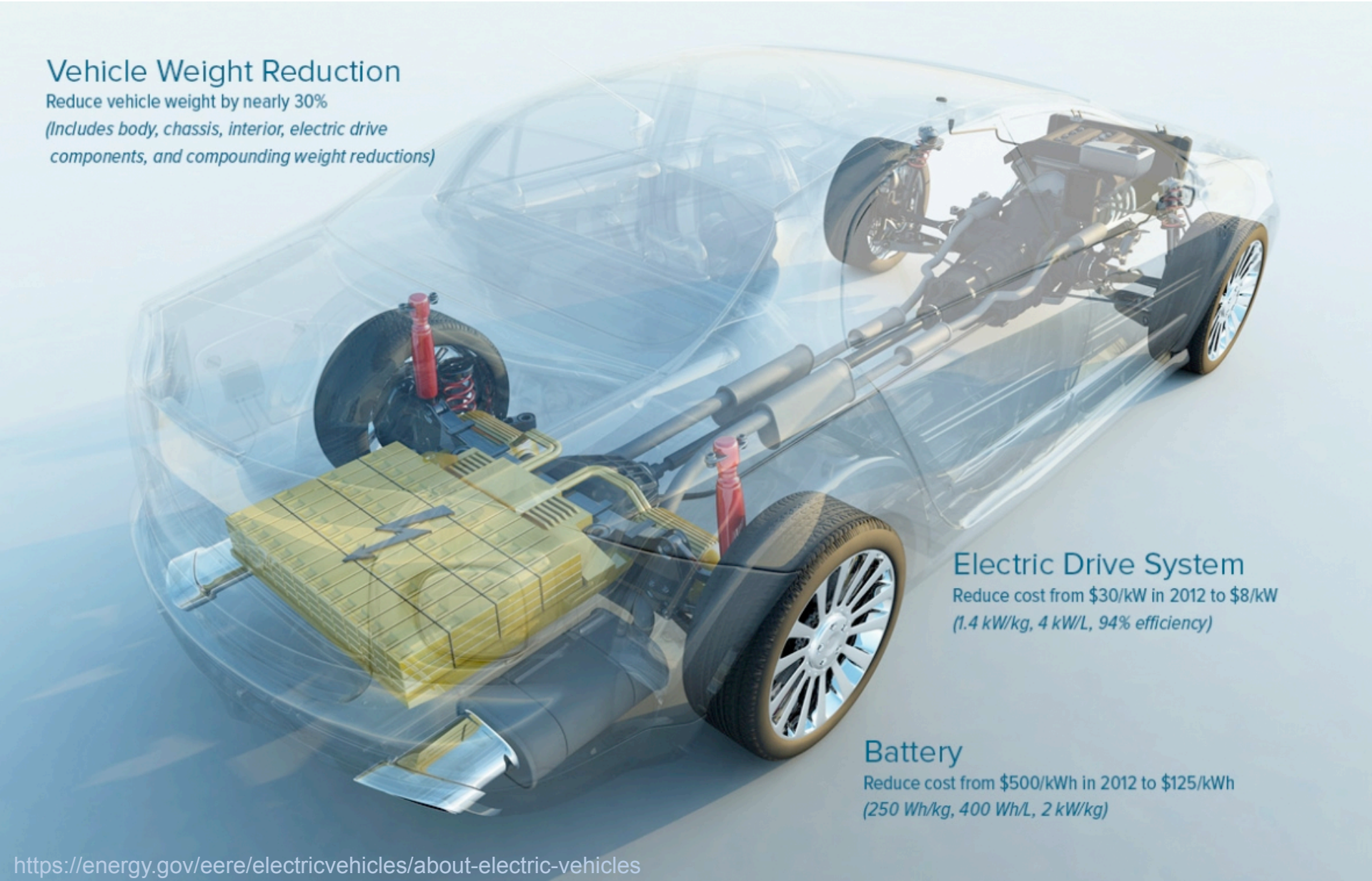
How have they achieved this?

- Paid ~1.9 million euros for 400 charging stations between 2008-2011
- Collaborates in Europe-wide urban EV project (exchange knowledge)
- Public-private partnership for car sharing: Statkraft (publically owned energy utility) sponsors Move About (car sharing company)

EV Parade for Al Gore and IPCC Chairman Rajendra Pachaur

Make public investments in R&D

DOE's EV Everywhere aims to increase the adoption and use of PEVs



https://energy.gov/eere/electricvehicles/about-electric-vehicles

Support supply chain development

With more research and incentives, we can break our dependence on oil with biofuels, and become the first country to have a million electric vehicles on the road by 2015

Recovery Act

Loans to EV factories

Grants to support OEM factories

22,000 charging stations

CAFE standards

Limited charging infrastructure

https://www.pinterest.com/stacey_ault13/cars/

Japan has more charging stations than gas stations

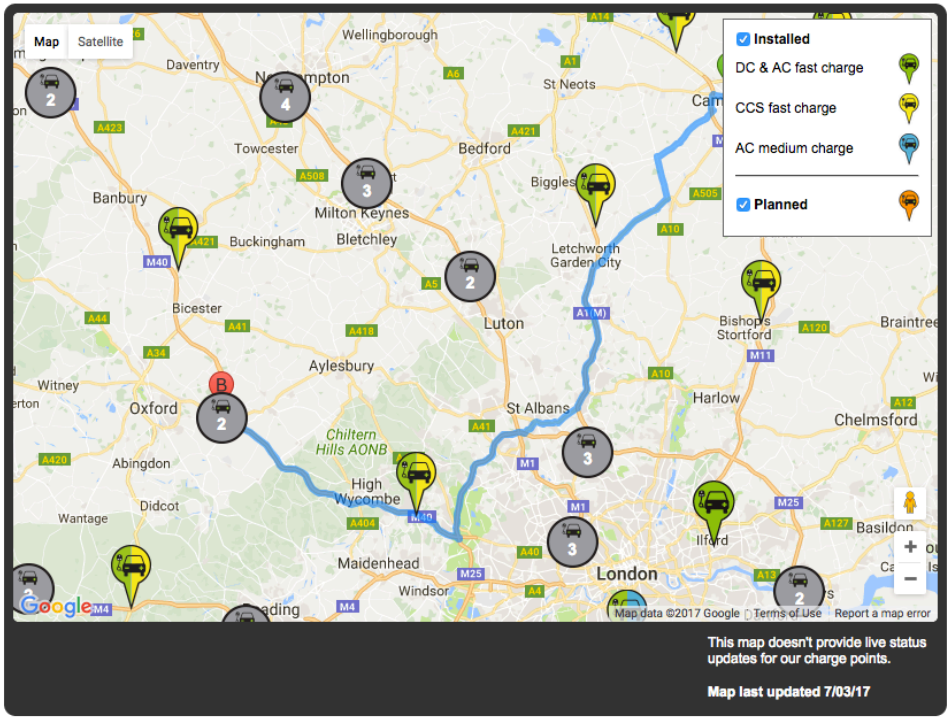
TOYOTA NISSAN HONDA MITSUBISHI

4 companies partner with Japanese government install 8,000 normal chargers and 4,000 quick chargers (expanding # chargers more than 2x)

2015

ecotricity

Britain's Greenest Energy Company



Electric Highway routefinder

Location postcode: CB21TP

Charge destination: Welcome Break Oxford, M40 N

Get directions

St Johns St, Cambridge CB2 1TP, UK

93.0 mi. About 1 hour 44 mins

1.	Head **west** toward **Bridge St**	262 ft
2.	Turn **left** onto **Magdalene St**	0.1 mi
3.	Turn **left** onto **Northampton St**	0.1 mi
4.	At the roundabout, take the **2nd** exit onto **Madingley Rd**	1.4 mi
5.	Turn **left** to merge onto **M11** toward **London**	1.3 mi
6.	At junction **12**, exit toward **Cambridge/Sandy/A603**	0.3 mi
7.	Merge onto **Grantchester Rd**	351 ft
8.	At the roundabout, take the **4th** exit onto **Barton Rd/A603**	0.5 mi
9.	At the roundabout, take the **1st** exit onto **Cambridge Rd/A603** Continue to follow A603	7.3 mi
10.	At the roundabout, take the **1st** exit onto **Ermine Way/A1198** Continue to follow A1198	2.9 mi
11.	At the roundabout, take the **1st** exit onto **Old N Rd/A1198**	1.5 mi
12.	At the roundabout, take the **3rd** exit onto **A505**	1.6 mi
13.	At the roundabout, take the **2nd** exit onto **Baldock Rd/A505** Continue to follow A505	8.3 mi
14.	At the roundabout, take the **1st** exit and stay on **A505**	0.5 mi
15.	Take the **A1** ramp to **Stevenage/London**	0.4 mi
16.	Merge onto **A1(M)**	15.1 mi
17.	At junction **3**, take the **A414** exit to **St Albans/Welham Green**	0.3 mi
18.	At the roundabout, take the **2nd** exit onto **N Orbital Rd/A414** Continue to follow A414	2.5 mi
19.	Continue straight onto **N Orbital Rd/A414**	0.5 mi
20.	At the roundabout, take the **3rd** exit and stay on **N Orbital Rd/A414**	2.0 mi
21.	At **Park Street Roundabout**, take the **2nd** exit onto **N Orbital Rd/A405**	0.6 mi
22.	At the roundabout, take the **2nd** exit and stay on **N Orbital Rd/A405**	0.6 mi
23.	At the roundabout, take the **1st** exit and stay on **N Orbital Rd/A405**	0.5 mi
24.	At the roundabout, take the **3rd** exit onto the **M25** ramp to **Heathrow Airport/M40 /M4/M3**	0.6 mi
25.	Merge onto **M25**	14.3 mi
26.	At junction **16**, exit onto **M40** toward **B'ham/Oxford**	29.5 mi
27.	At junction **8A**, take the **A418/A40** exit to **Aylesbury/Oxford**	0.2 mi
28.	At the roundabout, take the **1st** exit onto **Church Hill**	213 ft

Church Hill, Oxford OX33, UK

https://www.pinterest.com/stacey_ault13/cars/

Ford Focus Electric

Elektromobilitätsgesetz

Electromobility law

EVs are cool, right?


G-Wizz


Renault Twizy


Milkfloat


26,000km
14 countries
ELECTRICO
AE10 EKA

RACING GREEN ENDURANCE

RGE Aim:

"To inspire grassroots innovation and stimulate education through record breaking adventure & technology."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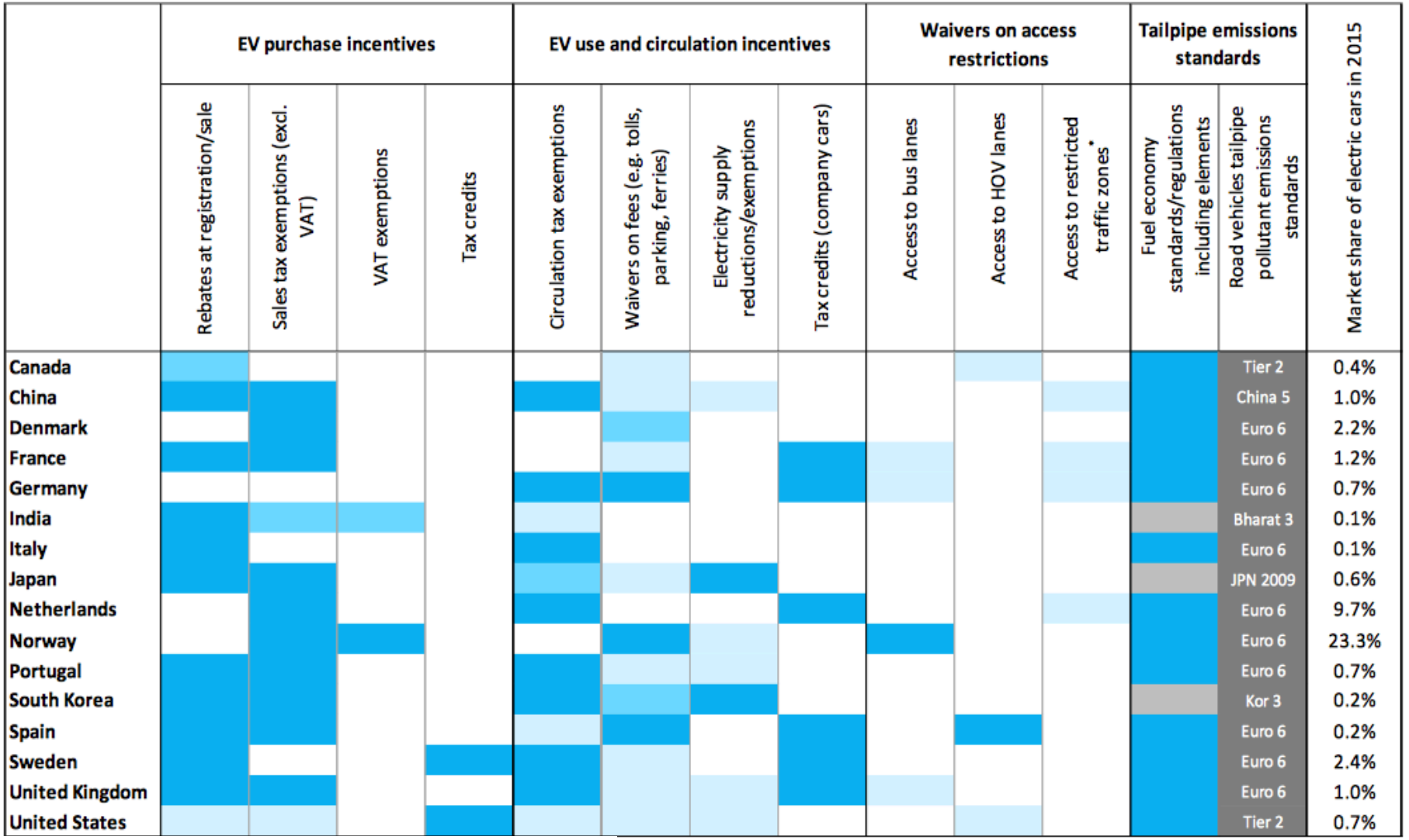
4. Summary & Outlook

Table 1 • Summary of policy support mechanisms for EV uptake in place in selected countries in 2015



Legend:
- No policy
- Targeted policy **
- Widespread policy***
- Nationwide policy
- General fuel economy standard, indirectly favouring EV deployment
- Euro 6 — Pollutant emissions standard in place in 2015

Notes:
- * Such as environmental/low emission zones.
- ** Policy implemented in certain geographical areas (e.g. specific states/regions/municipalities), affecting less than 50% of the country's inhabitants.
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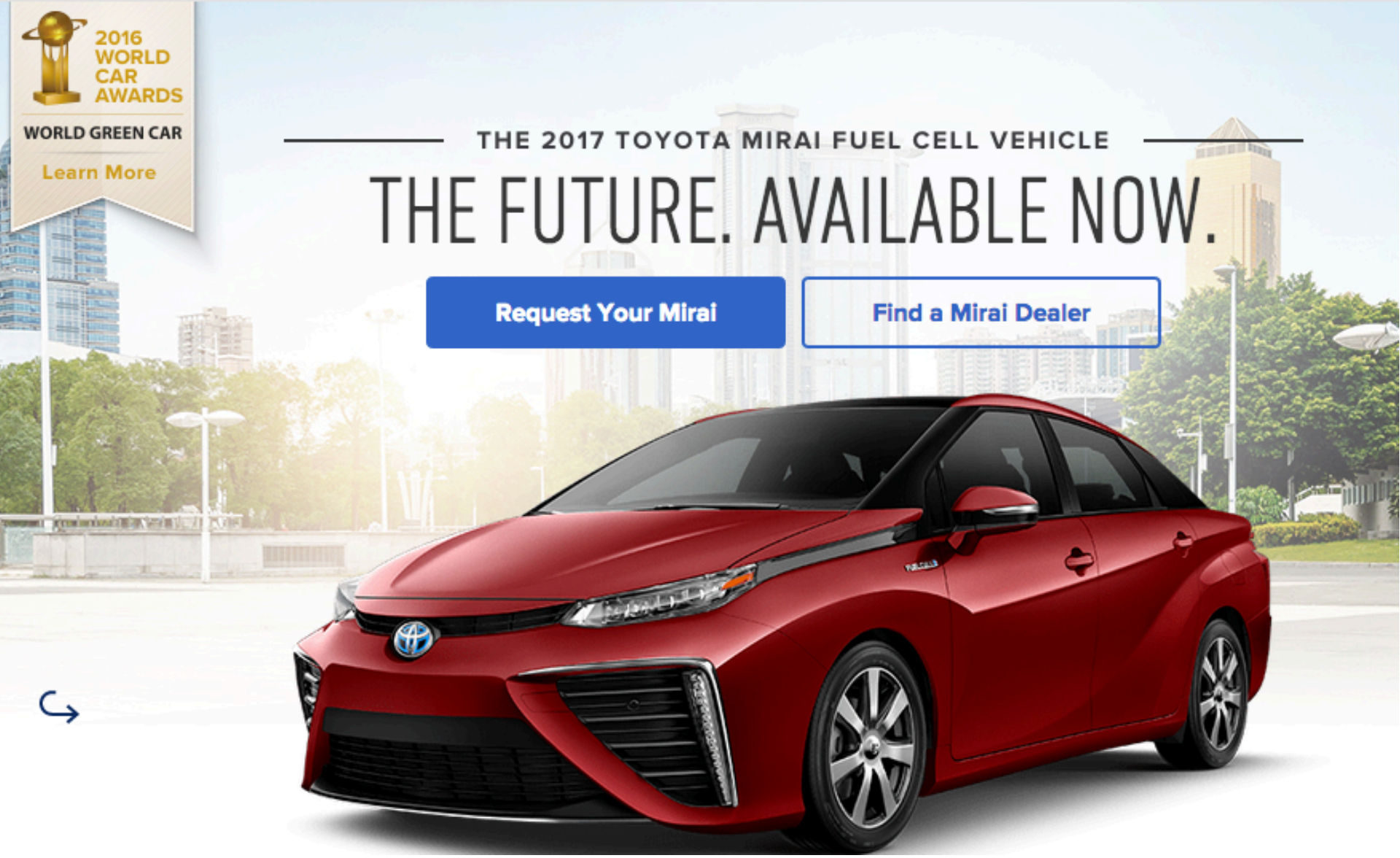


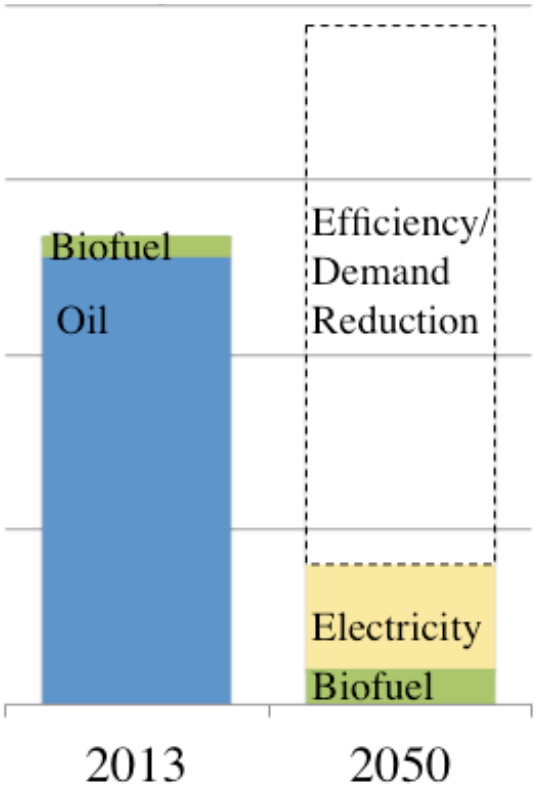
- Japan has third largest EV fleet in the world, yet has stopped investing in EVs as heavily
- Government has decided to try to transition to hydrogen economy with fuel cell vehicles

Summary of Solutions

https://www.pinterest.com/stacey_ault13/cars/

One billion electric vehicles…

- Means all cars are electric
- Will be enabled by policy
- Will be enabled by steep increase in electricity production



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