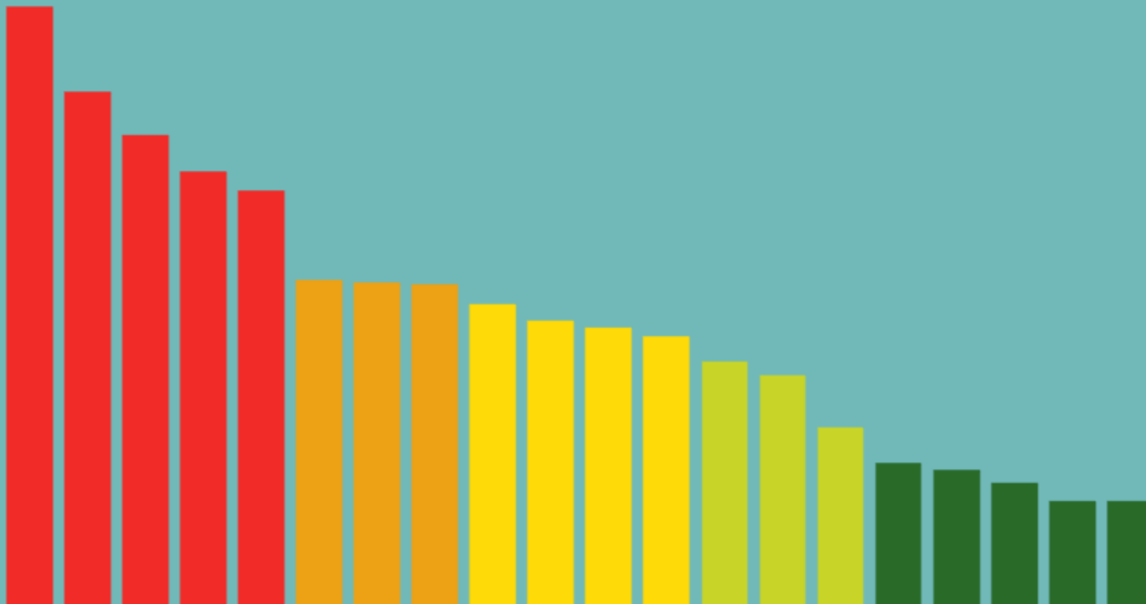


Shades of Green

Electric Cars' Carbon Emissions Around the Globe

Shrink That Footprint

Shrink That Footprint is an independent research group devoted to helping people concerned about climate change understand, calculate and reduce their carbon footprints.

In particular we focus on reducing emissions that arise from our housing, travel, food, product and service choices. Our Shrink Guide, carbon calculator and weekly posts can be found at: shrinkthatfootprint.com

Shades of Green:

Electric Cars' Carbon Emissions Around the Globe

Shrink That Footprint

Lindsay Wilson

February 2013

Executive Summary

Electric cars have the potential to reduce carbon emissions, local air pollution and reliance on imported oil. So it is little wonder governments around the world have supported their roll-out so keenly in recent years.

Although there is widespread understanding that electric cars can reduce carbon emissions, just how effective they are depends on the electricity they use. Given that the vast majority of the world's power generation is grid-tied, the carbon reduction potential of an electric car depends largely on where it is charged.

By comparing the carbon emissions of electric cars in twenty of the world's leading countries, this report highlights that electric vehicles must be used in tandem with low carbon power in order to maximize carbon emission reductions.

It shows that in countries with coal dominated power supplies electric cars generate carbon emissions four times higher than in places with low-carbon electricity.

Where power generation is coal dominated electric cars are the emissions equivalent of average petrol cars, while in countries with low carbon power they result in less than half the emissions of the best petrol hybrids.

The scale of this contrast reminds us that the climate benefits of going electric are not evenly shared around the globe.

Contents

1: Carbon Emissions of Electric Cars

To assess fully the climate impact of an electric car we need to consider the scope of emissions that occur in both the electricity supply and in vehicle manufacturing. Given that the vast majority of power generation is grid-tied, it makes sense to look at how electric vehicles perform using grid electricity.

To estimate the climate impact of consuming grid electricity we account for emissions that result from fuel combustion at power plants, upstream fuel production and the share of electricity lost in transmission and distribution.

On top of these three sources of grid based emissions it is also useful to consider vehicle manufacturing emissions. Electric cars result in more manufacturing emissions than traditional petrol vehicles, and have reduced lifetime mileage, which means per kilometer driven their manufacturing emissions are greater.

In this section we estimate the total emissions caused by using a grid powered electric car in 20 of the world's leading countries. For clarity we focus only on full electric vehicles and use national average grid emissions. As such these results may not be representative of individual grids within a country.

The key assumptions used in this section are that an electric vehicle has manufacturing emissions of **70 g CO_2e/km** over its lifetime, and that its wall-to-wheels energy use is **211 Wh/km**, or 34 kWh/100 miles, similar to a Nissan Leaf. Data for international electricity emissions factors is for 2009, and sourced from DEFRA in the UK (DEFRA 2012).

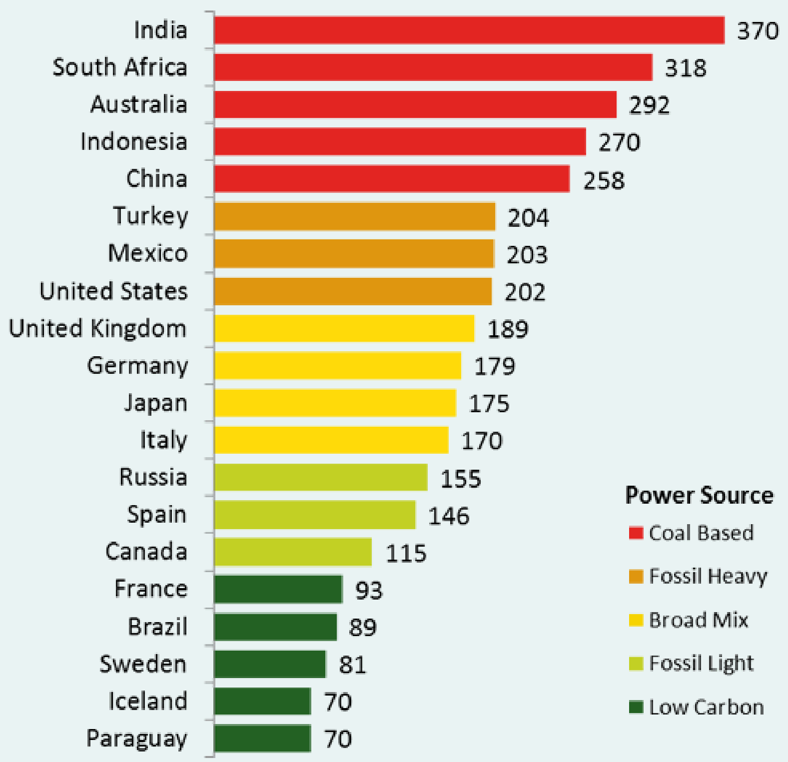
Further discussion of the importance of our manufacturing and energy use assumptions is detailed later in this report.

1.1 Power Source Matters

The first of the two core findings of this report is that the power source of an electric car matters.

The carbon emissions of grid powered electric vehicles are four times greater in countries with coal-dominated power generation than in those with low-carbon electricity (Figure 1.1).

Figure 1.1 Electric Vehicle Emissions: g CO_2e/km



Note: Results include emissions for vehicle manufacturing, direct grid emissions, indirect grid emissions and losses.

Sources: DEFRA, GHG protocol, IEA, EPA, GREET, LCA literature

Looking at the legend to the right we can see that the source of power is the key difference between electric vehicle emissions in different countries.

Given that manufacturing emissions account for 70 g CO_2e/km in each country, all the variation between Paraguay at 70 g and India at 370 g is a result of the difference in power sources.

Rather than discuss the results for each country we will draw out a few highlights from the analysis.

Paraguay is 'the greenest place on earth to drive an electric car'.

Hydroelectric exporter Paraguay edges out Iceland to claim top spot with driving emissions of just 70 g CO_2e/km, virtually all of which arises from vehicle manufacturing. The electricity used to drive a kilometer in Paraguay will generate less than a sixth of a gram of carbon emissions, significantly lower than solar power.

In China and India electric cars have bigger footprints

Due to the dominant share of coal generation in India, South Africa, Australia, Indonesia and China, grid powered electric cars produce emissions comparable to normal petrol vehicles. With emissions ranging from 370-258 g CO_2e/km electric cars generate significant emissions, many multiples of those using low carbon sources. In these countries electric vehicles will have limited climate benefit.

The US dash for gas is driving down electric driving emissions

In the decade from 1999 to 2009 the carbon intensity of electricity in the US fell by 15%, due largely to the increased use of natural gas. Based on 2009 data an electric vehicle using average US electricity generates 202 g CO_2e/km. The fast moving changes in the US fuel mix means this figure is significantly higher than will be the case for 2012 and that the footprint of driving an electric car continues to fall in regions using less coal.

The UK, Germany, Japan and Italy have moderate emissions

In the UK, Germany, Japan and Italy the broad mix of natural gas, coal, nuclear and hydro means the emissions of driving an electric car range from 189-170 g CO_2e/km.

In France, Canada and Brazil electric driving is very low carbon

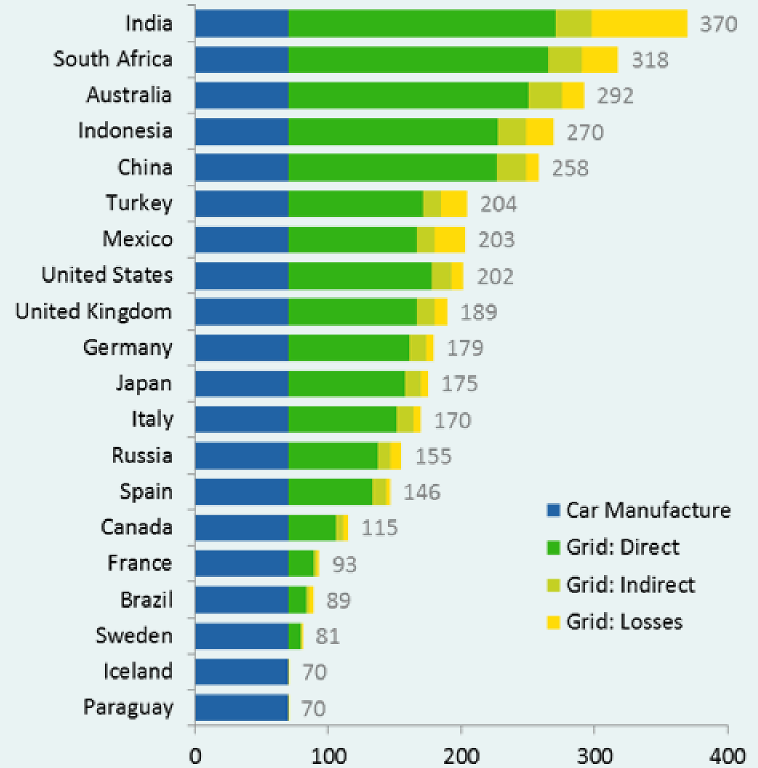
The dominance of hydroelectricity in Canada and Brazil, and that of nuclear energy in France, results in electric car emissions of just 89-115 g CO_2e/km, 70 g of which is manufacturing.

1.2 Breakdown of Electric Vehicle Emissions

To better understand how we arrived at these results it helps to look at the four components of each of our estimates. These include emissions from vehicle manufacture, fuel combustion at power plants, upstream fuel production and grid losses

By splitting our results into these four categories we can get a better picture of grid charged electric car emissions (Figure 1.2).

Figure 1.2 Emissions Breakdown: g CO_2e/km



Note: Results include emissions for vehicle manufacturing, direct grid emissions, indirect grid emissions and losses.

Sources: DEFRA, GHG protocol, IEA, EPA, GREET, LCA literature

For each country we have a constant value of 70 g CO_2e/km for manufacturing the electric car. Of the emissions that arise from the grid around 80% come directly from fuel combustion, 10% from fuel production indirectly, and a further 10% arise due to losses in transmission and distribution, though this varies from country to country.

When calculating all of the grid emissions we assumed the performance of the electric car to be of 211 Wh/km (34 kWh/100 miles). This is equivalent to official US EPA rating of the Nissan Leaf for its wall-to-wheels energy consumption.

This rating is multiplied by an emissions factor for direct grid emissions, indirect emissions and losses. These figures are for 2009 and were derived from DEFRA's 2012 GHG Conversion Factors (DEFRA 2012), which rely on data from the IEA and GHG Protocol.

These three types of grid emissions can be summarized as follows:

Grid: Direct - these emissions are often known as Scope 2 emissions. They include the carbon dioxide emissions that arise from fuel combustion in power plants.

Grid: Indirect - these emissions are often known as Scope 3 emissions. They include CO_2, N_2O and CH_4 emissions from fuel extraction, transportation, processing, distribution and storage.

Grid: Losses - these are emissions that arise producing electricity that is lost in transmission and distribution. These emissions are the direct and indirect emissions that were produced to provide lost electricity.

In order to understand the full climate impact of using grid electricity it is important to consider all three of these sources of emissions. A good example of this is India which has a similar fuel mix to South Africa, but much higher grid losses.

1.3 The rest of the world

Due to a desire for brevity and as a result of data restrictions this analysis only chose to focus on twenty countries.

The method used in this analysis however can be applied to any electricity grid in the world, assuming that you have an idea of its carbon intensity of supply, CO_2e/kWh.

In the absence of detailed data including indirect grid emission and grid losses, a rough estimate can be made using just the emissions that arise from power generation. The International Energy Agency provides such figures for 150 of the world's countries each year (IEA 2012). Based on 2009 data these are the Top 10 for the lowest and highest carbon electricity (Figure 1.3).

Figure 1.3 Top 10 Grid Emissions Factors

The Lowest	The Highest
1. Paraguay	1. Botswana
2. Iceland	2. Turkmenistan
3. Mozambique	3. Mongolia
4. Nepal	4. Kosovo
5. Albania	5. Estonia
6. Zambia	6. Cuba
7. Congo	7. Iraq
8. Ethiopia	8. South Africa
9. Norway	9. India
10. Tajikistan	10. Libya

Note: Based on 2010 data for CO2 emissions per kWh of electricity generation from 'CO2 Emissions from Fuel Combustion (IEA 2012)'.

Virtually all of the ten countries with the lowest emissions factors are dominated by hydroelectricity; in any of these an electric car creates less carbon than one using solar power. For any of the 10 countries with the highest carbon electricity electric cars are no better than petrol vehicles, and possibly worse.

2. Electric and Petrol Cars Compared

The scale of the variation between electric car emissions in different countries is quite stunning in itself. But by comparing these emissions to those from petrol vehicles we get a much better idea of the climate benefits of going electric.

Just as we did with electric cars we will consider the full scope of emissions that arise from petrol vehicles. This includes vehicle manufacturing, fuel combustion by the vehicle and the upstream emissions from fuel production, including extraction and refining.

The key assumptions we make to compare our electric emissions to petrol vehicle are as follows.

Manufacturing emissions of the petrol vehicle are assumed to be **40 g CO_2e/km** over its lifetime, which is less than 60% that of electric vehicles due to both a smaller total manufacturing footprint and greater lifetime mileage. This assumption is discussed in greater detail later in this report.

The carbon intensity of petrol combustion is **2.31 kg CO_2e/litre** and for petrol production it is **0.46 kg CO_2e/litre** (DEFRA 2012). Both these figures are for conventional mineral petrol. Thus they do not account for sources like biofuel blends or tar sands.

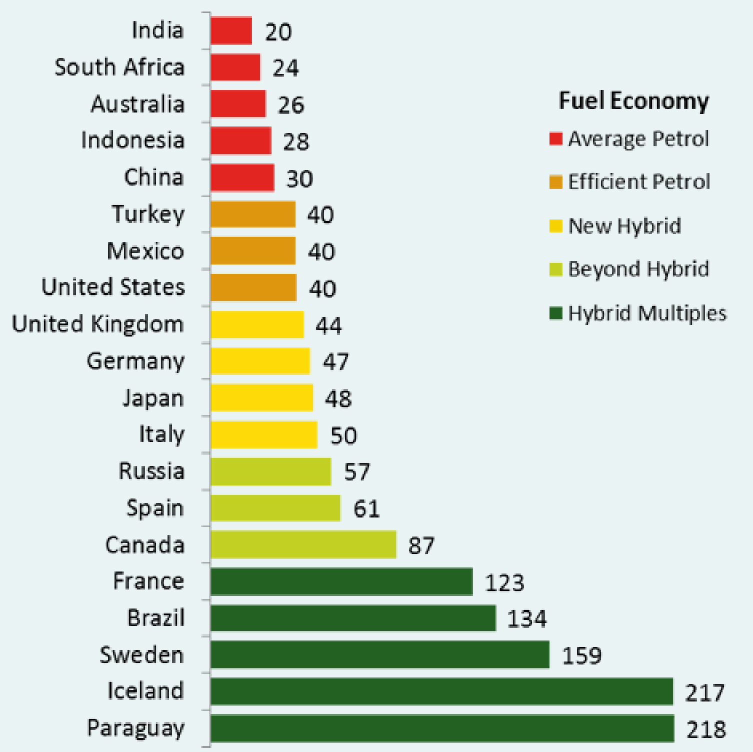
Having made these assumptions we are in a position to reverse engineer the equivalent petrol vehicle emissions for each of the twenty countries in this study. By calculating our results in terms of petrol emissions equivalent fuel economies we can analyse the impact of electric cars in a much more tangible way.

2.1 Emissions Equivalent Petrol Vehicle

The second of the two core findings of this report is that electric vehicle emissions range from similar to average petrol cars to less than half of the best hybrids depending on power source.

To help us understand this more easily we display the electric vehicle emissions from each country in terms of the emissions equivalent petrol vehicle, using miles per US gallon (MPG_{US}) as our means of description. (Figure 2.1)

Figure 2.1 Petrol Car Emissions Equivalent: MPG_{US}



Note: Results are the petrol car emissions equivalent to an electric vehicle in terms of mile per gallon (US).

Sources: DEFRA, GHG protocol, IEA, EPA, GREET, LCA literature

The results range from 20 MPG_{US} in India to 218 MPG_{US} in Paraguay. The legend to the right gives an idea of what type of petrol car, if any, results in similar emissions.

For the benefit of those unfamiliar with the US fuel economy standard of miles per gallon, we have converted these results into some other units (Figure 2.2).

Figure 2.2 Petrol Car Emissions Equivalent

Country	MPG (US)	L/100 km	km/L	MPG (UK)
Paraguay	218	1.1	93	261
Iceland	217	1.1	92	260
Sweden	159	1.5	68	191
Brazil	134	1.8	57	160
France	123	1.9	52	148
Canada	87	2.7	37	105
Spain	61	3.8	26	74
Russia	57	4.1	24	68
Italy	50	4.7	21	60
Japan	48	4.9	21	58
Germany	47	5.0	20	56
United Kingdom	44	5.4	19	53
United States	40	5.8	17	48
Mexico	40	5.9	17	48
Turkey	40	5.9	17	48
China	30	7.9	13	36
Indonesia	28	8.3	12	34
Australia	26	9.1	11	31
South Africa	24	10.0	10	28
India	20	11.9	8	24

Note: Results are the petrol car emissions equivalent to an electric vehicle in terms of mile per gallon (US).

Sources: DEFRA, GHG protocol, IEA, EPA, GREET, LCA literature

Once again, rather than discuss each country we will highlight a few main features of the results.

Hydro takes you a long way

In Paraguay, driving an electric vehicle creates emissions similar to achieving 220 MPG_{US} (1 L/100 km) in a petrol vehicle. Virtually all of the electric car emissions result from vehicle manufacturing, so this result is extremely sensitive to manufacturing assumptions.

In India and China electric and petrol cars have similar emissions

In India and China grid-powered electric cars produce emissions similar to traditional petrol vehicles. In India, a fully electric vehicle causes emissions comparable to a 20 MPG_{US} (12 L/100 km) petrol car, in China it is 30 MPG_{US} (9 L/100 km). This will vary between grid regions, and does not negate the fact that electric cars can potentially improve local air quality or reduce oil imports.

US electric vehicle emissions will soon be lower than hybrids

In our analysis electric vehicle emissions are equal to a gasoline fuel economy of 40 MPG_{US} (9 L/100 km), or similar to a modern petrol hybrid. This estimate however is based on electricity emissions from the 2009 grid mix and assumes typical petrol production emissions. Using an emissions factor specific to US petrol production raises the estimate to 43 MPG_{US}. Given the continuing shift from coal to gas electric vehicle emissions look set to outperform top hybrids nationally in the near term. As they already do in many lower carbon grid regions.

Electric cars match the best hybrids in the UK and Germany

In the UK, Germany, Japan and Italy electric vehicle emissions are comparable to top petrol hybrids; this is 44 MPG_{US} (5.4 L/100 km) in the UK, 48 MPG_{US} (5 L/100 km) in Germany and 50 MPG_{US} (4.7 L/100 km) in Italy. These results are around the threshold for a comparable petrol hybrid. With lower manufacturing emissions an electric car will be superior in terms of emissions.

In Canada and France electric cars can halve emissions

In Canada and France the petrol emission equivalences are 87 MPG_{US} (2.7 L/100 km) and 123 MPG_{US} (1.9 L/100 km) respectively. In these countries electric cars have the potential to halve total vehicle emissions. Manufacturing emissions account for around two thirds of electric car emissions in each of these countries, highlighting how important they become in low carbon vehicles.

2.2 Breakdown of Petrol Vehicle Emissions

As we did with electric vehicle emissions it is worth briefly looking at the three components that make up the equivalent emissions. These include emissions from vehicle manufacture, direct emissions from fuel combustion and indirect emissions from fuel production.

By splitting our results into these three categories we can get a better picture of equivalent petrol car emissions (Figure 2.3).

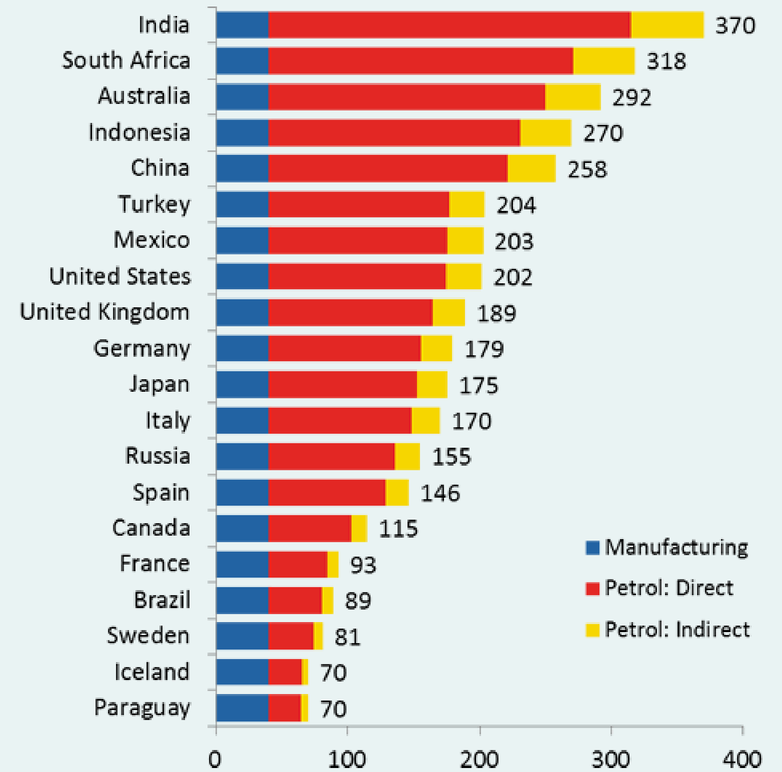


Figure 2.3 Petrol Emissions Breakdown: g CO_2e/km

Note: Results include emissions for vehicle manufacturing, direct fuel combustion and indirect fuel production.

Sources: DEFRA, GHG protocol, IEA, EPA, GREET, LCA literature

As already highlighted manufacturing emissions are a lower 40 g CO_2e/km for petrol vehicles. The direct CO_2 emissions that result from fuel combustion are often called Scope 1 emissions. The indirect production emissions that include CO_2, N_2O and CH_4 emissions are often called Scope 3 emissions.

3. The Importance of Manufacturing

One quite unique feature of this analysis is that it accounts for the manufacturing emissions, which have the potential to be very different between petrol cars and electric vehicles.

In fact our central estimates for electric vehicle are, on a per kilometer basis, almost double those of the petrol vehicle. This is accounted for by both energy intensive manufacturing and a lifetime mileage that is expected to be lower for an electric car, due to range restrictions and battery life.

Because our results are quite sensitive to these manufacturing assumptions we feel they are deserving of additional analysis.

3.1 Arriving at a sensible estimate

As a reminder our two core manufacturing assumptions were:

- **Electric Vehicle**: 70 g CO_2e/km
- **Petrol Vehicle**: 40 g CO_2e/km

For the petrol vehicle there is a large body of literature that places vehicle manufacturing emissions in the range of 4-7 kg CO_2e/kg curb weight of vehicle. Based on a small family vehicle, and allowing for the potential of hybrid technology which requires additional energy inputs, our figure for a petrol vehicle manufacturing footprint is 8 t CO_2e. Assuming a lifetime mileage of 200,000 kilometers we arrive at our central estimate of 40 CO_2e/km, in line with standard estimates.

Estimating manufacturing emissions for electric vehicles is more complicated, due to the limited number of studies and the great variation of their results.

A number of life cycle assessments place electric vehicle manufacturing emissions in the range of 50-90 g CO_2e/km, and most tend to assume a lifetime mileage of 150,000km given a single battery. A few examples are ~55 g CO_2e/km (Notter 2010), ~60 g CO_2e/km (Patterson 2011) and ~77 g CO_2e/km (Hawkins 2012), revised down in January 2013 corrigendum.

Depending on technology, system boundaries and inputs battery manufacturing alone is estimated to have a range of emissions of 0.1-0.3 t CO_2e/kWh (Contestabile 2012). For a 24 kWh battery that is a manufacturing footprint of 2.4-7.2 t CO_2e.

Our central estimate is for an electric vehicle manufacturing footprint of 10.5 t CO_2e, around 4 tonnes of which arises from battery manufacture. Given a lifetime mileage of 150,000 km using a single battery we have our 70 g CO_2e/km estimate.

3.2 Sensitivity to manufacturing assumptions

Because these estimates are central to our analysis, and are a source of considerable uncertainty within our results we have chosen to include a crude sensitivity analysis.

If we hold the petrol vehicle manufacturing emissions constant at 40 g CO_2e/km, and then vary the electric car manufacturing footprint we can assess the effect this has on our results.

For the electric car we will look at a high manufacturing emissions scenario of **90 g CO_2e/km**, and a low scenario of **50 g CO_2e/km**.

Given that manufacturing emissions are simply added to grid emissions these changes increase each result by 20 g CO_2e/km for the high scenario, or reduce each result by 20 g for the low scenario.

Much more interesting is the impact these changes have on the petrol car emissions equivalents (Figure 3.1).

Figure 3.1 Manufacturing Scenarios: MPG_{US}

Country	Low 50 g CO2e/km	Central 70 g CO2e/km	High 90 g CO2e/km
Paraguay	652	**218**	131
Iceland	646	**217**	130
Sweden	310	**159**	107
Brazil	226	**134**	95
France	198	**123**	89
Canada	119	**87**	69
Spain	76	**61**	52
Russia	69	**57**	48
Italy	59	**50**	44
Japan	57	**48**	42
Germany	55	**47**	41
United Kingdom	51	**44**	39
United States	46	**40**	36
Mexico	46	**40**	36
Turkey	45	**40**	35
China	33	**30**	27
Indonesia	31	**28**	26
Australia	28	**26**	24
South Africa	25	**24**	22
India	21	**20**	19

Note: Results are the petrol car emissions equivalent to an electric vehicle in terms of mile per gallon (US).
Sources: DEFRA, GHG protocol, IEA, EPA, GREET, LCA literature

Due to their large grid emissions the effect on coal dominated countries like India, Australia and China is relatively small. But as we go up the chart the impact becomes more pronounced.

For countries with broad fuel mixes the difference is significant. For Japan the high scenario falls to 42 MPG_{US} from 48 MPG_{US}, whereas for the low scenario it increases to59 MPG_{US}.

Finally in countries with low carbon electricity the change is dramatic. In Paraguay our central scenario was 218 $MPG_{US.}$ This falls to 131 MPG_{US} in the high scenario and jumps to 652 MPG_{US} in the low manufacturing emissions case.

These results stress the importance of considering manufacturing emissions in low carbon vehicles.

4. Sensitivity to Energy Use

The second assumption worthy of further discussion is that of electric vehicle energy use. For our main analysis we assumed a wall-to-wheels electricity use of 211 Wh/km (34 kWh/100 miles), similar to a Nissan Leaf.

To help understand the importance of the energy use of the electric vehicle we will consider two further scenarios. A low energy use scenario of **174 Wh/km** (28 kWh/100 miles), similar to a Scion iQ EV, and a high energy use scenario of **273 Wh/km** (44 kWh/100 miles), comparable to a Rav4 EV.

The effect of energy consumption is stronger as the electricity supply gets more carbon intensive (Figure 4.1).

Figure 4.1 Energy Use Scenarios: CO_2e/km

Country	Low 174 Wh/km	Central 211 Wh/km	High 273 Wh/km
Paraguay	70	**70**	70
Iceland	70	**70**	70
Sweden	79	**81**	84
Brazil	86	**89**	94
France	89	**93**	100
Canada	107	**115**	128
Spain	133	**147**	169
Russia	140	**155**	180
Italy	152	**170**	199
Japan	157	**175**	206
Germany	160	**179**	211
United Kingdom	168	**189**	224
United States	178	**202**	240
Mexico	179	**203**	242
Turkey	181	**204**	243
China	225	**258**	313
Indonesia	234	**270**	328
Australia	253	**292**	357
South Africa	274	**318**	391
India	317	**370**	458

Note: Results include emissions for vehicle manufacturing, direct grid emissions, indirect grid emissions and losses.

Sources: DEFRA, GHG protocol, IEA, EPA, GREET, LCA literature

There is nothing particularly surprising about these results. They show that even in countries with moderately carbon intensive power like the US, UK and Germany, the energy economy of the electric vehicle matters. The results are more intuitive in terms of petrol car emissions equivalents (Figure 4.1).

Figure 4.2 Energy Use Scenarios: MPG_{US}

Country	Low 174 Wh/km	Central 211 Wh/km	High 273 Wh/km
Paraguay	218	**218**	218
Iceland	217	**217**	217
Sweden	167	**159**	147
Brazil	143	**134**	120
France	133	**123**	109
Canada	98	**87**	74
Spain	70	**61**	51
Russia	65	**57**	47
Italy	58	**50**	41
Japan	56	**48**	39
Germany	54	**47**	38
United Kingdom	51	**44**	35
United States	47	**40**	33
Mexico	47	**40**	32
Turkey	46	**40**	32
China	35	**30**	24
Indonesia	34	**28**	23
Australia	31	**26**	21
South Africa	28	**23**	19
India	24	**20**	16

Note: Results are the petrol car emissions equivalent to an electric vehicle in terms of mile per gallon (US).

Sources: DEFRA, GHG protocol, IEA, EPA, GREET, LCA literature

For the coal dominated countries at the bottom of the table the effect of varying vehicle energy use is most pronounced, increasing or decreasing the equivalent fuel economy by 20%.

However, given that low energy use vehicles tend to be smaller, and high use ones larger, the variation in emissions shown here is likely to be mirrored by petrol vehicles of a similar class.

Lowering electric vehicle energy use has more emissions impact in places with high carbon electricity.

5. Comparisons to Diesel Vehicles

Due to their widespread popularity in Europe, and lower carbon emissions than conventional petrol cars, we have chosen to include a brief comparison between electric cars' carbon emissions and those of diesel vehicles.

5.1 Emissions Equivalent Diesel Vehicle

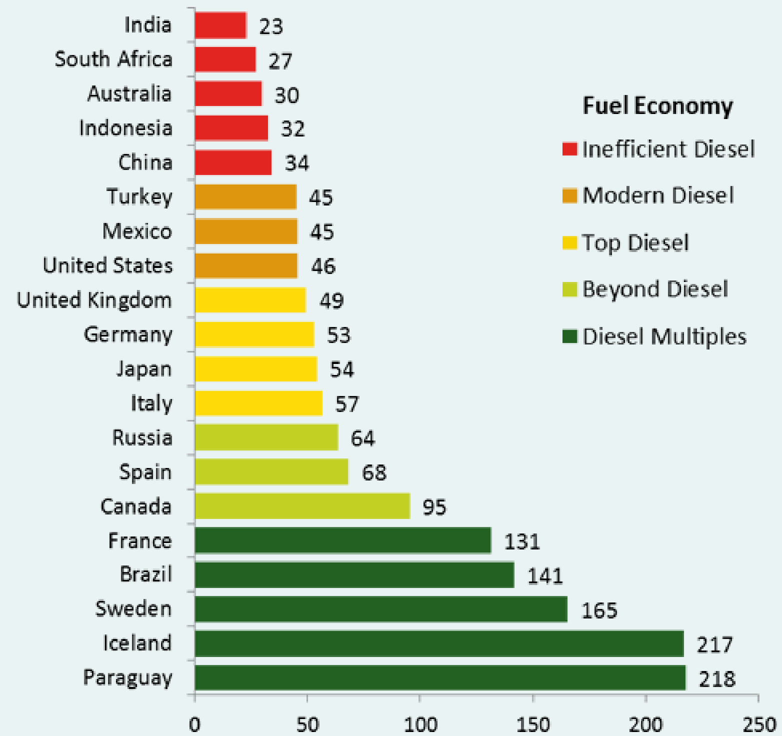
For our diesel manufacturing emissions we assume a figure of **35 g CO_2e/km** over its lifetime. This is slightly lower than our petrol estimate, due to its not needing hybrid technology.

The carbon intensity of diesel combustion is **2.68 kg CO_2e/litre** and for diesel production it is **0.56 kg CO_2e/litre** (DEFRA 2012). Both these figures are for conventional mineral diesel thus they do not account for things like biofuel blends or unconventional production.

In comparing diesel vehicles emissions to those from electric cars we return to using our central electric vehicle assumptions. They are manufacturing emissions of 70 g CO_2e/km and power consumption is 211 Wh/km.

Given that a diesel vehicle gets a fuel economy around 25% higher than comparable petrol vehicle the results in emissions equivalent miles per gallon (MPG_{us}) need to be analyzed with this in mind (Figure 5.1).

Figure 5.1 Emissions Equivalent Diesel Car: MPG_{US}



Note: Results are the diesel car emissions equivalent to an electric vehicle in terms of mile per gallon (US).

Sources: DEFRA, GHG protocol, IEA, EPA, GREET, LCA literature

Because diesel has both higher combustion and production emissions per unit volume, the electric car emissions equivalent is higher in terms of fuel economy.

Between Spain and India these fuel economies are 10-15% higher than our results for the emissions equivalent petrol vehicle. But given that diesels achieve around 25% higher fuel economy than similar non-hybrid petrol vehicles, top diesels are a match for and can even outperform petrol hybrids. As a result our legend classifications are slightly altered compared to petrol vehicles.

Once again for the benefit of those not familiar with the US fuel economy standard we can translate these results to other units (Figure 5.2).

Figure 5.2 Diesel Car Emissions Equivalent

Country	MPG (US)	L/100 km	km/L	MPG (UK)	Increase
Paraguay	218	1.1	93	261	0%
Iceland	217	1.1	92	260	0%
Sweden	165	1.4	70	198	4%
Brazil	141	1.7	60	170	6%
France	131	1.8	56	158	7%
Canada	95	2.5	41	115	9%
Spain	68	3.4	29	82	11%
Russia	64	3.7	27	76	12%
Italy	57	4.2	24	68	12%
Japan	54	4.3	23	65	12%
Germany	53	4.5	22	63	13%
United Kingdom	49	4.8	21	59	13%
United States	46	5.1	19	55	13%
Mexico	45	5.2	19	55	13%
Turkey	45	5.2	19	54	13%
China	34	6.9	15	41	14%
Indonesia	32	7.2	14	39	14%
Australia	30	7.9	13	36	14%
South Africa	27	8.7	11	32	15%
India	23	10.3	10	27	15%

Note: Results are the diesel car emissions equivalent to an electric vehicle in term of fuel economy. Increase is the difference to petrol.

Sources: DEFRA, GHG protocol, IEA, EPA, GREET, LCA literature

The fifth column shows the increase in fuel economy relative to the petrol vehicle emissions equivalent.

For countries with a broad fuel mix, like the UK and Germany, an efficient diesel car will result in similar emissions to an electric vehicle. In the UK the emissions breakeven for diesel is around 59 MPG_{UK}, while in Germany it is about 4.5 L/100 km.

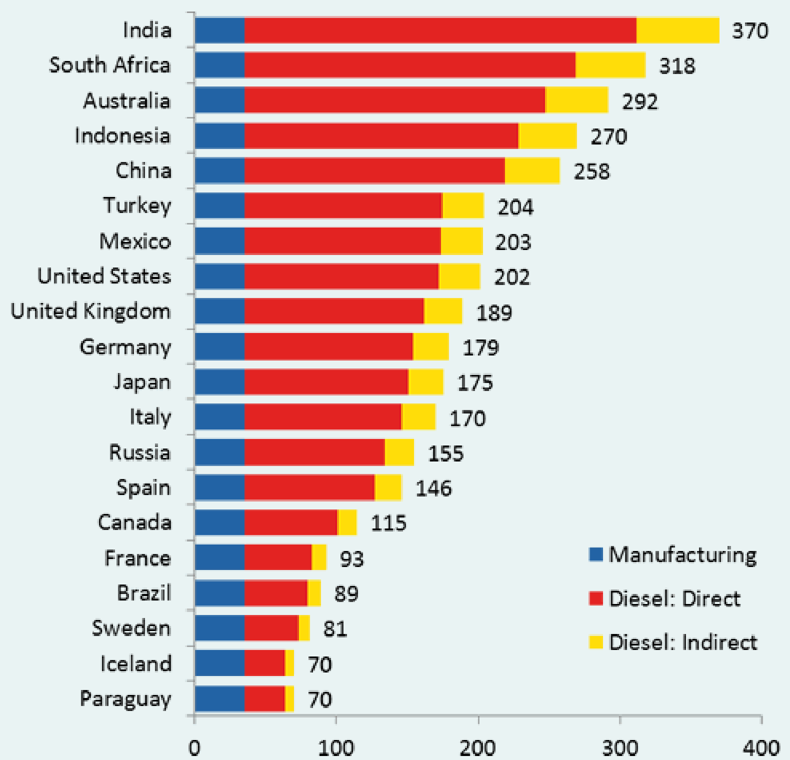
While efficient diesels have lower carbon emissions compared to conventional petrol cars it is worth noting that they are less desirable in terms of local air pollution and black carbon emissions. Particulate filers correct these problems to a degree.

In terms of comparison to electric vehicles an efficient diesel's carbon emissions are broadly comparable to a new petrol hybrid.

5.2 Breakdown of Diesel Emissions

For the purpose of highlighting the distinction between manufacturing, fuel combustion and fuel production emissions it is worth looking briefly at the breakdown of emissions for each country (Figure 5.3).

Figure 5.3 Diesel Emissions Breakdown: g CO_2e/km



Note: Results include emissions for vehicle manufacturing, direct fuel combustion and indirect fuel production.

Sources: DEFRA, GHG protocol, IEA, EPA, GREET, LCA literature

Despite looking almost identical to the petrol breakdown there are a few subtle differences.

As already explained we have used a slightly lower manufacturing emissions estimate to account for the diesel not using hybrid technology. Secondly indirect diesel emissions make up a larger share of fuel emissions. So the importance of fuel production emissions rises as a result of both of these differences.

6. Limitations of the Analysis

By limiting ourselves to a discussion of carbon emissions in twenty countries this report is able to highlight a number of key points. Before discussing these in the conclusion it is worth noting the key limitations of this study.

This analysis does not include any discussion of local air pollution, vehicle operation costs and vehicle purchase prices. Although these issues are outside the scope of this work we recognize they are each central to assessing the desirability of electric cars going forward. The ability of manufacturers to reduce purchase prices in particular will be key to determining electric vehicle market penetration in coming years.

The most striking limitation of the analysis itself is that it treats each country as single electricity grid. While this is useful for illustrative purposes, and is correct for many physically smaller countries, it should not be taken as given.

In the US for example the carbon intensity of electricity can be three times higher in some grid regions than others. So while our figures are representative of the national average it should not be assumed this is accurate at the local level.

A second limitation of this analysis is that it only does a straight comparison between full battery electric vehicles and petrol vehicles. Though we have adjusted our petrol vehicle manufacturing figures to include hybrid vehicles, this does not cover plug-in hybrids.

Due to the large variety in battery sizes, electric range and extended range fuel economy it is very difficult to make generalizations about plug in hybrids.

A third, though less important, limitation of the study is that it assumes all petrol and diesel comes from conventional mineral sources. This means our results do not account for the inclusion of unconventional oil, like tar sands, or biofuels. In countries with large shares of either this could alter the petrol or diesel equivalent emissions.

Finally, although we have used the most up to date literature available there will always be uncertainty surrounding the estimation of vehicle manufacturing emissions, in particular those of electric vehicles.

Conclusion

Electric cars' carbon emissions are four times greater in places with coal dominated electricity than in countries with low carbon power.

These figures serve as a reminder that electric cars are not a standalone technology for carbon reduction, but that they must be deployed together with low carbon power to maximize their potential.

In countries with coal dominated power generation electric vehicles do little to reduce carbon emissions when compared to petrol vehicles. In countries with a broad fuel mix they are equivalent to the best petrol hybrids or efficient diesels. In places with low carbon power they are more than twice as good as the best combustion engines.

Though often overlooked, vehicle manufacturing emissions are increasingly important in low carbon vehicles, and should be considered to fully understand the benefits of new vehicles.

In its whole this analysis serves to show that the climate benefits of going electric are not evenly shared around the world.

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