Data Story: "Are Electric Vehicles Viable in 2021?"

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I. Data Story Summary

My data story answers the question: "Are Electric Vehicles Viable in 2021?". Specifically, it first presents the European Union's 2035 proposal for 100% reduction in emissions for new car and van sales [1] as context for the story, and then takes the reader through three components of viability:

1. Are electric vehicles (EVs) actually better for the environment? Specifically: Do EVs produce fewer CO_2-equivalent emissions than conventional vehicles? (**Environmental viability**)
2. Are electric vehicles more expensive to run than conventional vehicles? (**Economic viability**)
3. Are electric vehicle batteries good enough in 2021 to make common long-distance journeys? Specifically: How far can electric vehicles batteries travel on a single charge, and are there enough charge points? (**Convenience/Usability**)

By taking the reader through each of these components, the data story implements the "gradual reveal" narrative pattern [2], allowing the reader to more easily grasp the many facets of viability and come to a conclusion themselves based on these components (the "users-find-themselves" pattern). The "rhetorical question" pattern is also used in the title of the story to encourage the reader to think more deeply and personally on the data and ideas presented.

A final conclusion is made at the end of the story, stating that "Electric vehicles are more viable than ever before" as they are better for the environment and cheaper to run than conventional vehicles, and current battery ranges and charge point locations allow make common long and short distance journeys feasible.

The story follows the well-respected 'Martini Glass' narrative structure [3], which starts with a 'kicker' message (the EU proposal), moves onto an author-driven stage where the reader is guided through the data in a fixed structure (Charts A, B and B2), and finally ends with a user-driven exploratory stage (Chart C).

II. Dataset Summary

Table 1 (Appendix A) gives a summary of the eight datasets used for the story including their names, variables used and sources.

For Chart A, datasets 1, 2, and 3 were used. Datasets 1 and 2 were standardised by matching the energy generation methods in 2 to the names in 1, and summing some sub-categories together—such as the four types of combustible fuel sources. The total emissions (E_c^T) for each country c were then calculated with:

$$E_c^T = \sum_{m \in \mathbf{M}} E_m * \frac{P_{cm}}{P_c} \tag{1}$$

where $\mathbf{M}$ is the set of standardised production methods, E_m is the median emissions for m (dataset 2), P_c is the total energy produced by country c and P_{cm} is the energy produced for country c using method m. The exhaust emissions and electricity consumption per km (W) are calculated by averaging over dataset 3 grouped by vehicle type. The electricity production emissions for a given country c are then calculated with:

$$E_c^P = W * E_c^T \tag{2}$$

For Chart B, datasets 3, 4, 5 and 6 were used. The weekly fuel price data (P_f) for each fuel type f in dataset 5 was averaged over a 28 week period to more closely match the timescale of dataset 6. The average fuel consumption and electricity consumption (C_f) were obtained from dataset 3 using the same process as (W) in Chart A.

For the second variant of Chart B (incorporating the upfront vehicle cost), the fuel data from dataset 3 was adjusted to include the average vehicle cost (U_f) over the average vehicle lifespan (L_f) for each fuel type (f):

$$P_f^{adj} = P_f + \frac{U_f}{L_f} \tag{3}$$

In Chart C datasets 7 and 8 provided latitude and longitude) points, and the average EV travel range was obtained from dataset 6. The positions were filtered to remove points outside of mainland Britain, and the cities were ordered by population and limited to the 50 largest. To calculate if points were within the reachable radius, the standard Haversine formula (Appendix B) for arc-distance on a sphere was used.

As well as the datasets listed in Table 1, the following sources were used for single data values (e.g. the average CO_2-equivalent emissions produced per kWh during battery manufacture): [4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14].

III. Visualisations

A. Breakdown of CO_2-equivalent Emissions

1) Description

Chart A is a stacked bar chart which shows the breakdown of CO_2-equivalent emissions per km into four components: vehicle manufacture, battery production, upstream emissions (fuel and electricity production) and exhaust emissions (Figure 1). The chart shows breakdowns

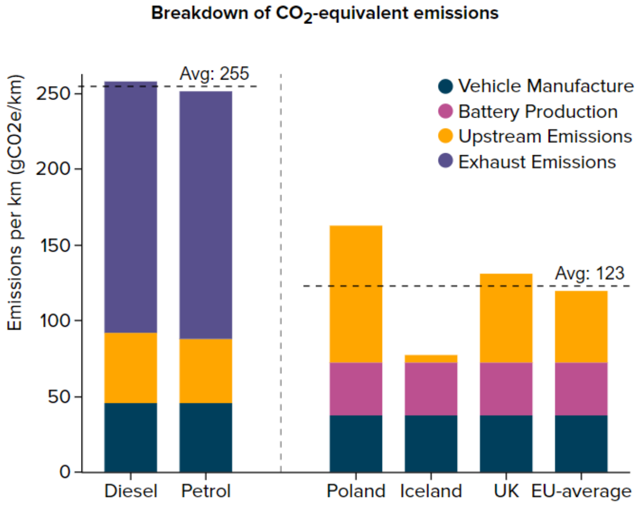

Figure 1: Screenshot of Chart A showing the breakdown of CO_2-equivalent emissions for diesel and petrol vehicles and for electric vehicles in four countries.

for diesel and petrol vehicles, and for electric vehicles in four countries to answer question 1 (Section I).

2) Justification

This chart was chosen to allow a comparison between the environmental emissions of conventional vehicles, and EVs so the reader can see that EVs are much more environmentally friends.

The choice was made to further split the EV category into four countries so that a range of carbon-weightings in power grids could be shown. Poland was found to be one extreme with 11% renewable energy, and Iceland as the other with 99.99% renewable energy. Since even Poland's bar is much lower than both the petrol and diesel ones, this shows the reader that EVs are better environmentally regardless of the energy production methods used.

A stacked bar chart has been chosen to allow for this easy comparison of the total emissions for each vehicle type—as aligned length is one of the most accurate methods of data presentation [15]—whilst also showing the distribution of emissions between the different components, which allows the reader to better understand where the emissions come from in a vehicle's lifetime.

Horizontal lines are used to highlight the averages of the two vehicle categories (conventional and electric) and allow for easier comparison of the bar heights by reducing the height encodings to compare from 6 to 2. Furthermore, the Gestalt principle of continuity [16] allows for dashed lines to be used and perceived as a complete line, whilst not breaking up the stacked bars where they cross.

3) Narrative Design Patterns

The visualisation uses the "compare" narrative design pattern [2] to highlight the differences between conventional and EV emissions. This allows the reader to start the data story with a clear motivation—electric cars are better for the environment.

Furthermore the "rhetorical question" pattern is used in the pre-chart paragraph ending: "With all of that taken into consideration, are they even better for the environment? Does it depend on the energy production methods being used?", to preemptively answer questions the reader may have been thinking.

4) Strengths and Weaknesses

The chart clearly conveys the desired message: that EVs are much more environmentally friendly than conventional combustion vehicles—regardless of the method of energy production used.

Un-ordered, contrasting colours were chosen to clearly distinguish the different categories as a retinal visual encoding, and the category orders were chosen to avoid similar colours next to each other.

The Gestalt principles of proximity and similarity [16] are also used effectively to visually group the bars relating to EVs, with the dashed vertical line further reinforcing this separation and grouping, allowing for easier comparisons.

The relative heights of bar categories can be hard to compare [17], however, this is not too large of an issue as the main purpose of the visualisation is to compare the total heights.

5) Improvements

One improvement that could be added would be to add error bars to the top of each bar chart showing the uncertainty around the values, as a number of averages are used (e.g. average battery capacity, average vehicle production emissions).

Moreover, the electric-vehicle bars could be labelled with their height as a percentage of the combustion vehicles' height to more-clearly show that electric cars produce less than 50% of the emissions of conventional vehicles.

Another improvement, that would supplement the message shown, would be to add a visualisation showing another environmental aspect such as manufacture waste.

B. *Vehicle (Purchase and) Running Costs per km Over Time*

1) Description

Chart B is a line chart which encodes vehicle running costs per km against time for petrol, diesel and electric vehicles (Figure 2).

Chart B2 is another line chart with the same categories and scale, but also includes the upfront vehicle purchase cost divided over the lifetime mileage of the vehicle type.

Together, these charts present the user with the data to find the answer to question 2 (Section I).

2) Justification

A line chart was chosen to allow the reader to notice trends in how the costs have varied up to the current point and predict future changes.

The Gestalt principle of proximity [16] is employed in Chart B to highlight the difference in costs between electric and conventional vehicles. The petrol and diesel lines are in close proximity which the brain pre-attentively groups together, and there is a much larger gap to the electric line.

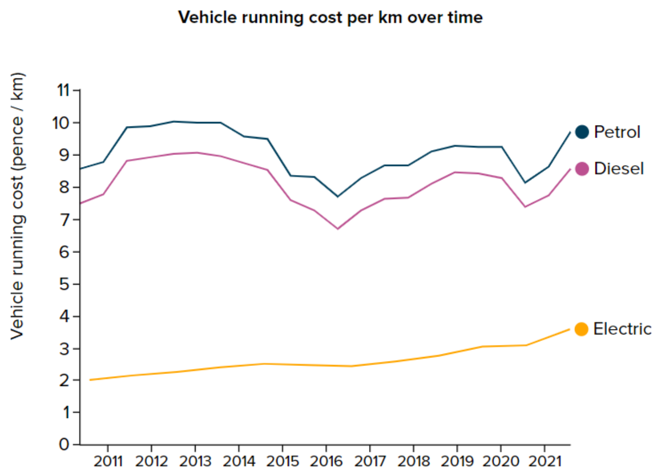

Figure 2: Screenshot of Chart B showing the running cost of diesel, petrol and electric vehicles over time.

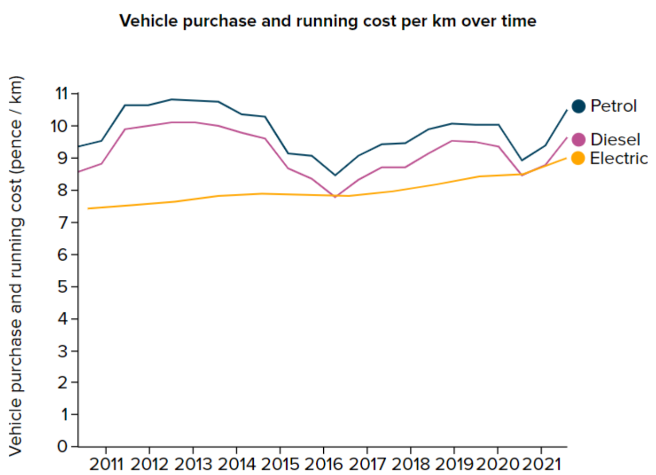

Figure 3: Screenshot of Chart B2 showing the running cost of diesel, petrol and electric vehicles over time adjusted with the upfront cost averaged over the lifetime miles of the vehicle type.

3) Narrative Design Patterns

The presentation of Chart B followed by Chart B2 is an example of the "gradual reveal" narrative pattern [2]. This breaks the cost expenditure down into two parts and allows the reader to more easily understand the content presented. The "repetition" pattern is also used by presenting the same categories on the same scales with slightly adjusted data. This emphasises the change, and emphasises the fact that EVs are still cheaper on average even with the change.

The chart is also combined with the "rhetorical question" pattern in the sub-heading: "What about their much higher cost-to-buy?". This presents a common rebuttal to EVs and guides the reader to look for the answer to the question in the next chart—causing them to more-deeply examine the chart and data.

4) Strengths and Weaknesses

The use of a line chart is effective in allowing the reader to notice and predict trends, as well as compare the vertical positions (costs) for each of the three categories.

The use of colours as a retinal encoding for the line categories allow for easier distinguishing of the lines than just the end-labels, as well as allowing for the reader to be able to distinguish the path of intersecting lines.

The minimalist design of coloured lines on a large white background allows the reader to clearly identify the important data in the chart. Moreover, the fact that the fuel data is aggregated over the same time frame as the electric data means that the three lines can more easily be compared between, and trends more easily followed as the lines are smoother.

One weakness of the visualisation is that the y-axis is in pence per km, which, whilst it is a standard unit of measurement, is not one commonly seen, and so the numerical values may not be accessible to the layperson. On the other hand, the actual values of the data points are less important than the relative heights of the lines to each another.

Another weakness, due to lack of available data, is that the graph only shows the last 10 years, a longer time frame would allow the reader to make a better prediction for the future. Due to similar data availability issues, the chart only shows data for electric cars which are charged at home, not at public charge points.

5) Improvements

To improve the visualisations, the electric category could be further down to incorporate additional cost factors such as whether the vehicles are charged at home or at public charge points, or incorporating the cost of installing a home charging solution.

Furthermore, a region around the lines could be shaded to show the uncertainty in the measurements due to the averages and assumptions made.

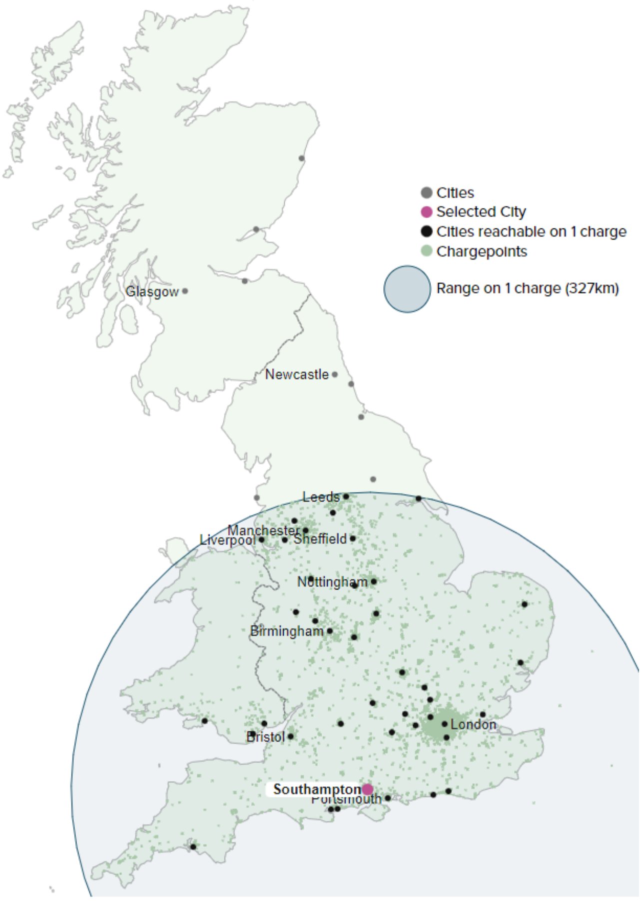

Figure 4: Screenshot of Chart C where the reader has selected Southampton as the starting location.

C. Interactive Travel Range Map

1) Description

Chart C is an interactive geographical chart of the UK in which the reader can select a city (point) to visualise the travel range of an electric car on a single charge (Figure 4) Once a point is selected, an area around that point with radius 327km appears representing the maximum distance that can be travelled on an average single EV battery charge [4] to allow the user to explore question 3 (Section I). Also within that circle, a number of green points appear showing the position all of the charge points in that radius.

2) Justification

The use of a geographical map chart is appropriate for this visualisation at it enables the reader to see the reachable distance on a map of the UK—something they are already familiar with—allowing them to intrinsically relate the presented data with their own previous experiences. This, combined with the fact that the reader can interactively select the starting location, facilitates the "familiarisation" design pattern.

A further benefit of the interactive, explorable nature of the chart is removal of bias: by allowing the user to select any starting point, there is no prescribed route or starting city shown.

Since the chart is interactive and changes on the reader's click—a large, shaded circle appears, and the cities inside that radius get darker—this highlights the key idea of the visualisation: the reachable distance.

3) Narrative Design Patterns

This chart utilises four narrative design patterns [2]. Firstly "user-find-themselves" which allows the visitors to come to a conclusion regarding the usefulness of electric car batteries based on their own investigation and interaction ("exploration" pattern). This leads to the "familiarisaion" pattern as discussed above—the visitor can select a starting city which tailors the displayed data to their own personal experience. Finally the "gradual reveal" pattern is implemented due to the charge point brushing [18]: where the charge points only appear on the visualisation when a city is clicked. This reduces chart clutter and makes the initial visualisation easier to read

4) Strengths and Weaknesses

This chart shows a novel visualisation that clearly conveys the desired message of the chart through simple data presented on a map which is familiar to all visitors. The interactivity of the chart is effective in allowing deep exploration and reasoning about the data shown, and will highly increase user engagement and understanding.

The use of brushing [18] to hide the charge points and only reveal them on click, as well as the cities being a lighter shade of grey aside from those inside the reachable distance allows for an easier understanding and more-readable chart in the first instance which reveals more data as the user interacts with it. The hiding of charge points also makes the cities more readable and clearer to the visitor that these are the interactable elements in the visualisation.

One weakness of that chart is possibly that the choice of green dots to represent charge points on the green background of the map may not provide enough contrast to be accessible to all users, however this choice does enable city points and their names to stand out more and be more readable as the many charge point dots are light in colour. However, the place names are still difficult to read over the charge point dots.

The main drawback of this visualisation is that the chart only shows straight-line distances, and does not account for the actual positioning or length of roads between destinations.

5) Improvements

One improvenent to the chart would be some way to represent re-charing of the vehicle, for example a second range radius which shows the total range if another charge is carried out en route.

Aside from this, the chart could be improved by extending to to other countries aside from the UK, and/or having some way of picking any location on the map, and not just the marked city points.

IV. Conclusion

This data story presents a clear message that EVs are "more viable then ever before" in 2021, through a clear

Martini-glass structure, incorporating many narrative design patterns and interactive elements to engage and inform the user. This is carried out effectively using three visualisation-types and supporting text.

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Appendix A. Data Sources

	Name	Variables Used	Chart	Source	Bias/Source Notes
1	**Gross and net production of electricity and derived heat by type of plant and operator** [19]	Country, Energy production volume, Production method	A	Eurostat (EU)	None (European Union Source)
2	**Emissions for each electricity supply technology** [20]	Production technology, Lifecycle emissions	A	IPCC (UN)	None (United Nations Source)
3	**Car fuel and emissions information** [21]	Fuel Type, wh/km, mpg, CO2 emissions/km	A, B	Vehicle Certification Agency (Gov. DfT)	None (Government source)
4	**Electric Vehicle Database** [4]	Vehicle cost, Battery travel range, Year first available, Electricity Consumption	B, C	EV Database UK	None (Independent, non-funded organisation)
5	**Weekly road fuel prices** [22]	Date, Petrol Pump Price/litre, Diesel Pump Price/litre	B	Gov. BEIS Dept.	None (Government source)
6	**Average unit costs and fixed costs for electricity for UK regions** [23]	Year, Average variable electric unit cost	B	Gov. BEIS Dept.	None (Government source)
7	**National charge point Registry** [24]	Latitude, Longitude, Connector (Type, Output Power, Status)	C	Gov. Dept for Transport (DfT)	None (Government source)
8	**United Kingdom Cities Database** [25]	Name, Latitude, Longitude, Population	C	National Geospatial-Intelligence Agency via Sim-pleMaps.com	Aggregated from authoritative sources and processed for accuracy

Table 1: Summary of the data sources used for the data story. For information regarding the processing and joining of datasets see Section II.

Appendix B. Other Equations

Haversine Formula for arc-distance on a sphere between two ⟨latitude, longitude⟩ pairs $\langle \phi_1, \lambda_1 \rangle$, $\langle \phi_2, \lambda_2 \rangle$:

$$d = 2R \arcsin\left(\sqrt{\sin^2\left(\frac{\phi_2 - \phi_1}{2}\right) + \cos\phi_1 * \cos\phi_2 * \sin^2\left(\frac{\lambda_2 - \lambda 2_1}{2}\right)}\right) \tag{4}$$

where R is the radius of the sphere (here that is the Earth's radius: 6,371 km).