TRANSITIONING TO SUSTAINABLE MOBILITY

An introduction to using energy and emissions data to inform strategic decisions

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INTRODUCTION: MAKING LONG-TERM DECISIONS IN A COMPLEX, CHANGING WORLD

The automotive industry must play its role in delivering net zero by 2050, by creating low and zero emissions vehicles. The strategic decisions that will deliver this vision will take time to filter through into new vehicle designs, supply chains and consumer behavior. However, they must be taken now.

Demand for vehicles and fuel is increasing as the world becomes more global and urban. Every increase in a vehicle's emissions is multiplied as more people drive them. We must therefore make vehicles as sustainable as possible.

But what does maximum sustainability look like? What fuel and propulsion methods should you use? What raw materials should you pursue? Where should you manufacture?

These big decisions will set corporate direction for years, and will be hard to change once committed to. Yet they will be impacted by complex trade-offs beyond your control, from land use, to infrastructure, to competition for energy resources from other industries.

When setting a strategy for 30 years or more, how can we ensure we take all the competing factors into account to make the best decisions? This paper uses worked examples to explore how to think about these decisions, and discusses how to take this thinking into your organization.

SUSTAINABLE MOBILITY – THE SIZE OF THE EMISSIONS-REDUCTION PRIZE

There are a lot of vehicles on the road, and numbers will only grow. In 2022, just shy of 80 million vehicles were sold. This is projected to grow to nearly 96.5m by 2029[1].

This is particularly driven by Asia, where private ownership of cars will increase sharply with urbanisation and the continued growth of the middle classes. In the USA there are 890 vehicles per thousand people vs 221 vehicle per thousand people in China[2]. That's a lot of room to grow.

Figure 1
Global light vehicle sales by 2029
Source: IHS Markit

[1] 7 year light vehicle sales forecast data, IHS Markit

[2] List of countries by vehicles per capita, Wikipedia

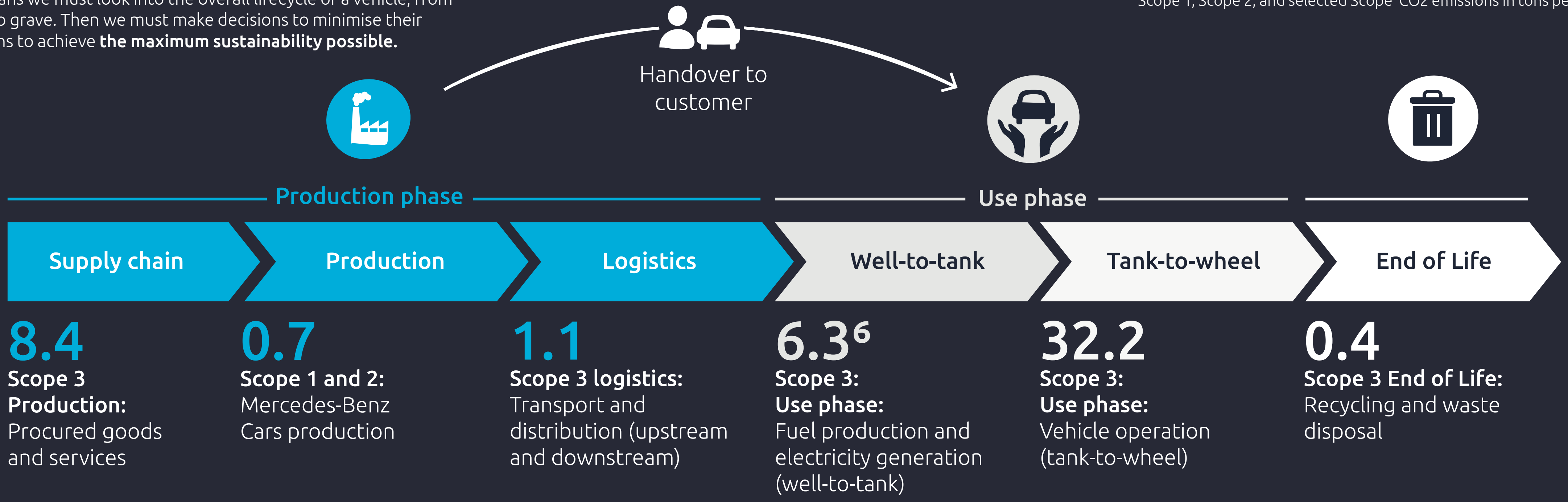
Every one of these vehicles has a carbon footprint defined by its materials, production, and its in-use emissions – ie those produced by the energy source that powers it, whether that is combusting oil, or generating electricity or fuel. The latter is partly beyond the control of the automaker, and will vary by location (depending on energy mixes, distance from fuel source, etc) but must be considered when making sustainable design choices.

Every vehicle sold multiplies those emissions. But, equally, every reduction in emissions is multiplied.

This means we must look into the overall lifecycle of a vehicle, from cradle to grave. Then we must make decisions to minimise their emissions to achieve **the maximum sustainability possible.**

Figure 2

Scope 1, Scope 2, and selected Scope CO_2 emissions in tons per vehicle.



Source: Mercedes-Benz (page 139)

NAVIGATING THE MANY TRADE-OFFS OF YOUR NET ZERO TRANSITION

Some things are clear. A low or zero carbon vehicle cannot have an internal combustion engine (ICE) – even one that uses cleaner fuels – since these will still produce polluting NOx. The alternative options on the table are a battery electric vehicle (BEV) or a hydrogen fuel cell electric vehicle (FCEV).

Most automotive manufacturers recognise that, although many are pursuing multiple routes. Is this a good strategy?

Given that even these mechanisms will not be completely emissions-free in the short term – since electricity and hydrogen are not yet produced by 100% renewable energy – there is also the need to use digitalisation and automation to minimise fuel consumption. But how?

Beyond that, there is a need to rethink the design, development and manufacturing of the vehicle. It is important to understand the material, and how it is assembled, in order to minimise supply chain emissions, maximise recyclability, and create a design that will reduce energy needs in use – eg through lighter materials.

For EVs, we must look at the choice of battery materials to understand how the raw material will be mined, and which energy source and how much energy is needed for the production of the battery, so we can understand the CO_2 impact per kWh.

All these factors must be balanced. To understand this, and make the right decision, we need a deep understanding of the full life cycle, which understands how all the overlapping factors influence each other. We call this an integrative Life Cycle Assessment, or iLCA. This gives us the insights to make smart strategic decisions.

In the following sections we explore how we might assess some key factors in the lifecycle emissions of a vehicle in order to reach a final strategic decision. For the purposes of providing generalisable examples in this paper, these are top-level and designed to be illustrative of how we might reach results, rather than de facto recommendations, which will always be bespoke to a company, depending on its strategy and markets.

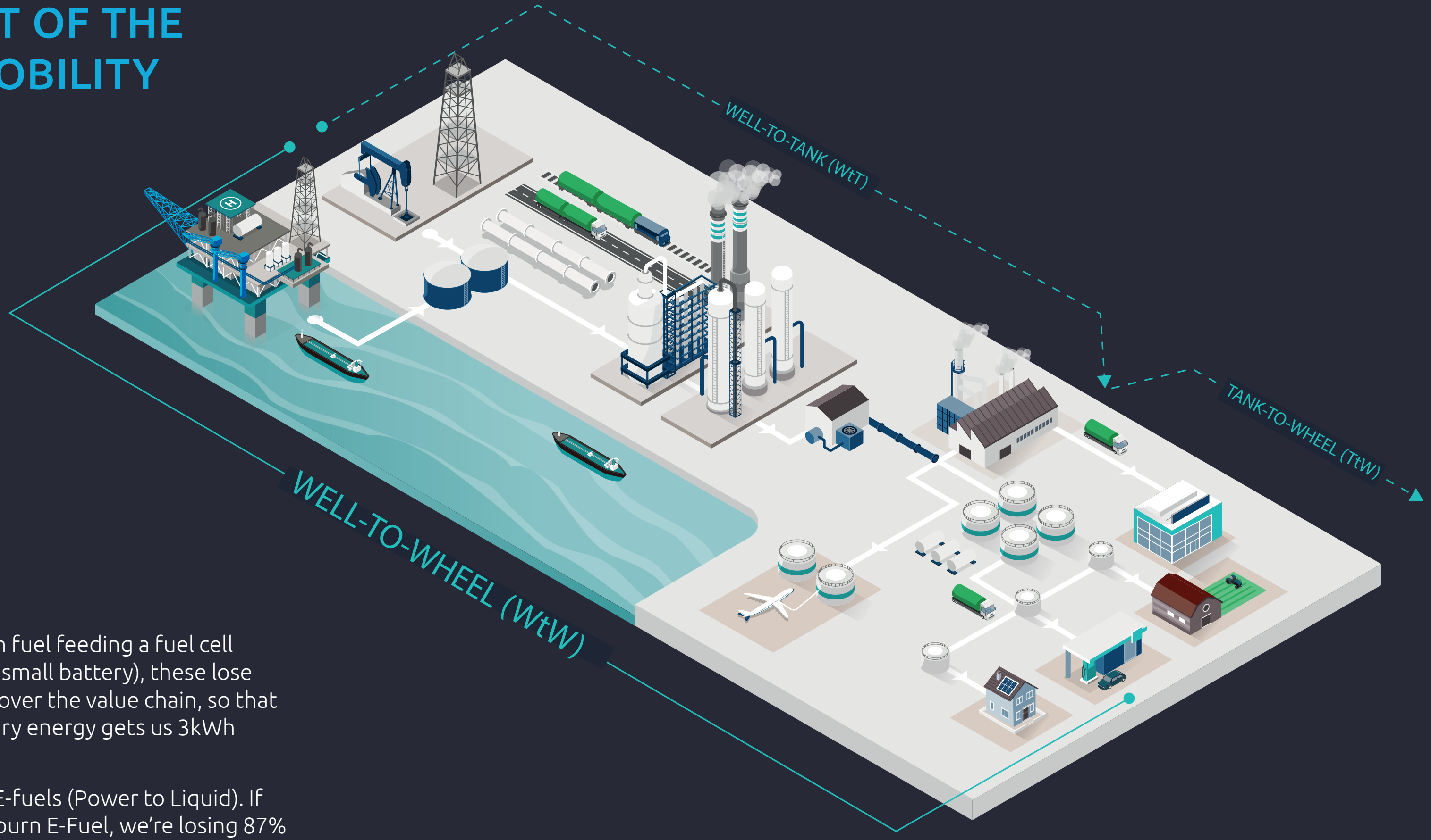
ASSESSMENT EXAMPLE 1: THE IMPACT OF THE ENERGY SOURCE ON SUSTAINABLE MOBILITY

Let's assume we are looking at three low carbon propulsion approaches for our next range of vehicles, and our goal is maximum emissions reduction:

- **Electric**
- **Hydrogen**
- **E-fuels**

Which one should you pursue to achieve the most sustainable vehicle?

We can inform this decision by looking at the complete flow from the source to the vehicle, a process known as: WELL-TO-WHEEL (see illustration).



In an electrical power source – ie a battery – we lose about 24% of the energy between the primary energy source and the propulsion. This is due to losses between generation, transmission, charging and in the battery itself. In other words, for 10kWh of energy generated, we will get 7.6kWh of driving power.

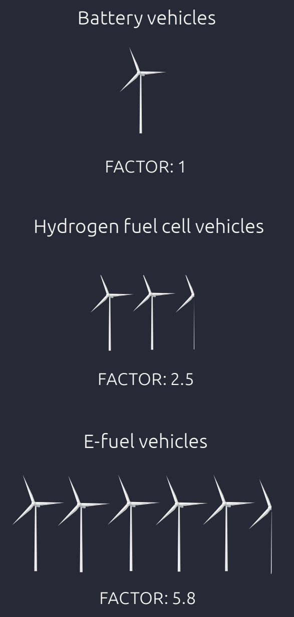
If we look at hydrogen fuel feeding a fuel cell (which also involves a small battery), these lose about 70% of energy over the value chain, so that same 10kWh of primary energy gets us 3kWh of driving.

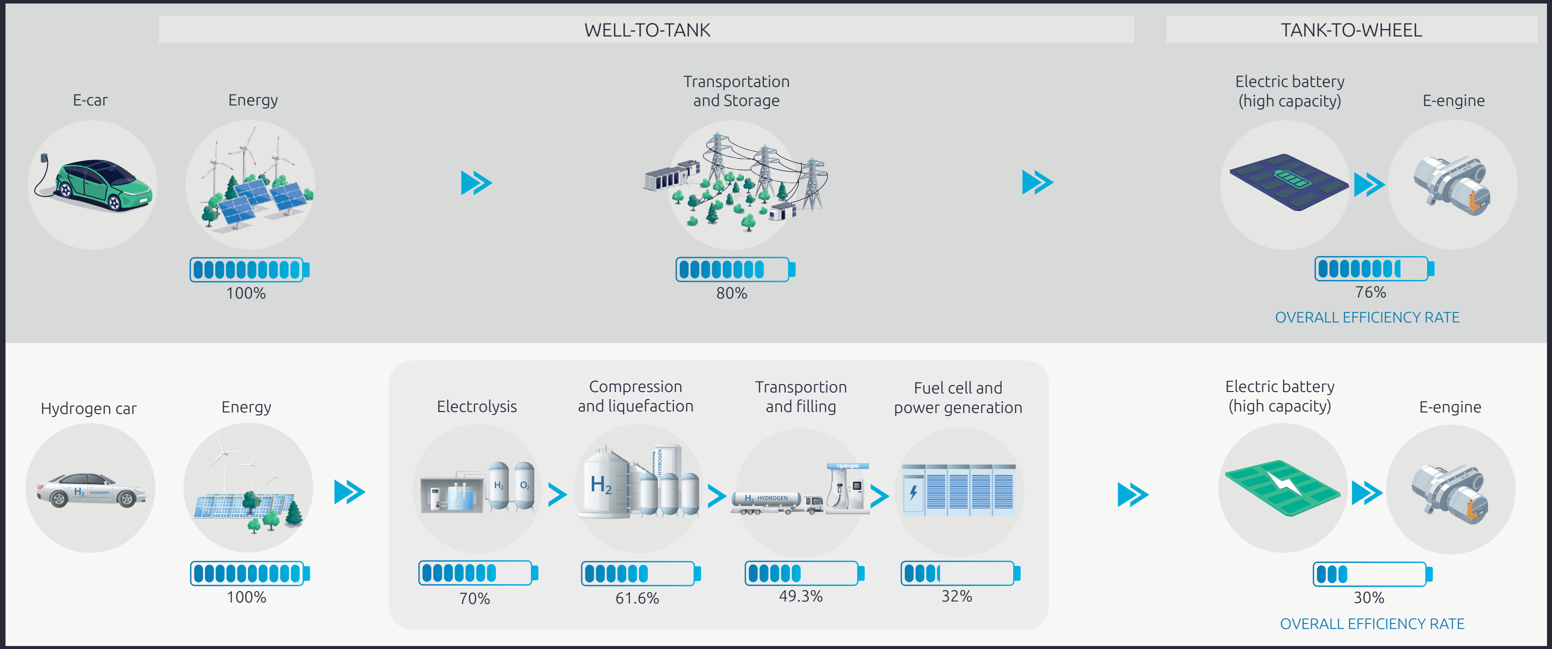
Then, we can look at E-fuels (Power to Liquid). If we're using an ICE to burn E-Fuel, we're losing 87% of the energy along the way, so 10kWh of primary energy produces just 1.3kWh for driving. E-fuels are only CO2 neutral if they are produced by green energy and if CO2 is directly taken out of the air. E-Fuels are still polluting (i.e NOx,...).

Once we know the energy requirements we need to consider where this energy comes from.

For this analysis, let's assume we are aiming to produce this power with renewable energy. To produce the primary energy we must build renewable energy sources such as wind turbines. If we have lower overall efficiency, we need more turbines to produce the same energy (see diagram). That infrastructure comes with its own environmental cost – in the short term the opportunity cost of replacing fossil fuel power, in the long term the need to build more infrastructure to meet higher power demands.

Energy input equivalent per unit of energy output





Source: VW news stories

So we see in the case of cars – when looking at the whole picture – battery vehicles represent the more sustainable option in most instances.

This picture could of course become much more detailed in a bespoke analysis. Hydrogen has benefits over electricity such as being easier to store and transport, so there will be exceptions where those benefits take precedence, such as vehicles that need to travel long distances away from electricity sources, or if countries have green hydrogen infrastructure but not green electricity.

The point is that only by a full analysis well-to-wheel, considering the energy requirements and emissions of energy sources, can we get a reliable picture of the most sustainable decisions.

ASSESSMENT EXAMPLE 2: THE IMPACT OF THE BATTERY AND THE GRID

Now let's assume, following the above assessment, we want to pursue a BEV strategy.

Of course, the battery itself comes with a CO2 footprint. How can we minimise this?

The size of the battery's CO2 footprint is highly influenced by the energy source which is used to power the manufacturing facility making the cells, and the battery system.

There are very large differences between countries' power mix which feeds their electricity grid. For example, looking at three major manufacturing countries, we see the CO2 emission for a kWh of power is (as of August 16th,2022) :

South Korea	502g CO_2e/kWh
France	77g CO_2e/kWh
Germany	279g CO_2e/kWh

We must also consider the transport of raw materials and assembled parts – how far will they travel? Which vehicles will transport them? What are those vehicles' carbon emissions per km?

Then we must look at the emissions to produce the energy for EV charging, based on the grids in different markets. Again, we see huge differences between countries, which will impact our roadmap to net zero vehicles (August 16th,2022):

New South Wales (AUSTRALIA)	742g CO_2e/kWh
Sweden	26g CO_2e/kWh

Finally, we need to consider recycling - today it is already possible to recycle up to 95% of a battery.

In all cases, we need models of each country's energy mix. Into these, we can add our own data on materials used, locations, and vehicle charging needs to get reliable projections of lifetime emissions.

The point here is that all of this needs to be properly assessed in order to create a roadmap for vehicles with "clean" propulsion, using 100% renewable energy, and a circular economy of parts, with close to ZERO impact on the environment.

PLANNING YOUR NET ZERO TRANSITION STRATEGY

As this paper shows, the maximum sustainability for most light vehicles' mobility involves electrification and renewable energy to power both production and charging.

But of course that is not the end of the story. Within that broad claim, many companies and regions will face specific challenges and opportunities that change the calculus. Other vehicles and products will have different optimal routes. Companies wishing to make the transition to net zero must understand the best route for them.

The way to do that is a lifetime transition assessment. This must consider internal and external factors relating to fuel source, energy required to generate that fuel, efficiency from generation to transportation to use, as well as the myriad ways vehicles can be optimized either in design or use.

Good transition planning requires an understanding of many different factors, not just in isolation, but within an ecosystem where resources have upper limits, and other industries may make decisions that compete with your own.

Making good decisions needs highly sophisticated system-of-systems modeling, combining your own engineering and supply chain models with climate, energy, demographic and macroeconomic models.

Perfect future forecasting is of course impossible, but by taking a system-of-systems approach it is possible to build up highly predictive models of what any long-term decision will look like. From there, you can make the best technology decisions, from propulsion mechanisms, to assisted driving, to the systems engineering that holds it all together.

About the author

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Klaus's 22-year career in the Automotive industry began in the Research and Development departments of FORD Europe and AUDI.

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