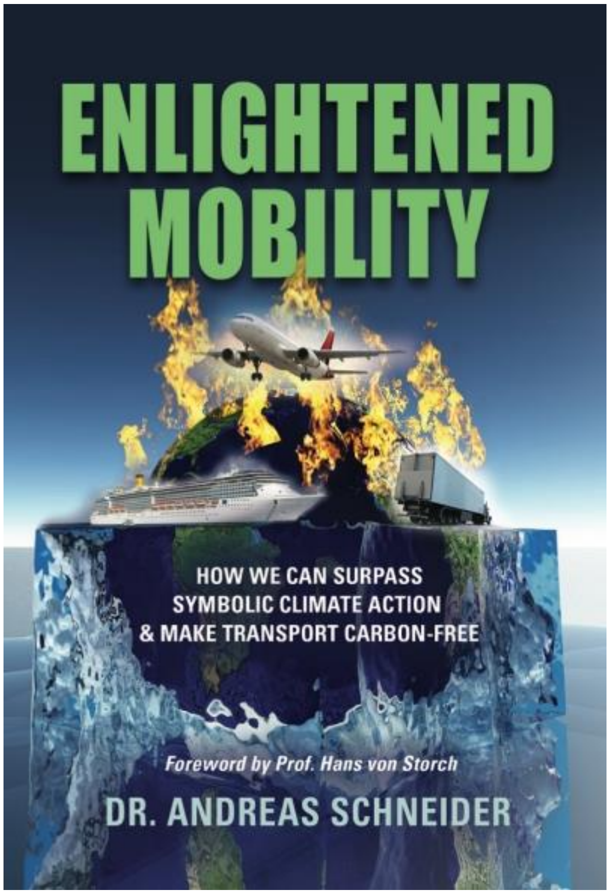

Enlightened Mobility applies a fact-based approach to outline the most beneficial strategies to combat climate change in transportation. The book explains why our current national thinking is doomed to fail and suggests a new mobility paradigm.

ENLIGHTENED MOBILITY:

How we can surpass symbolic climate action & make transport carbon-free

By Dr. Andreas Schneider

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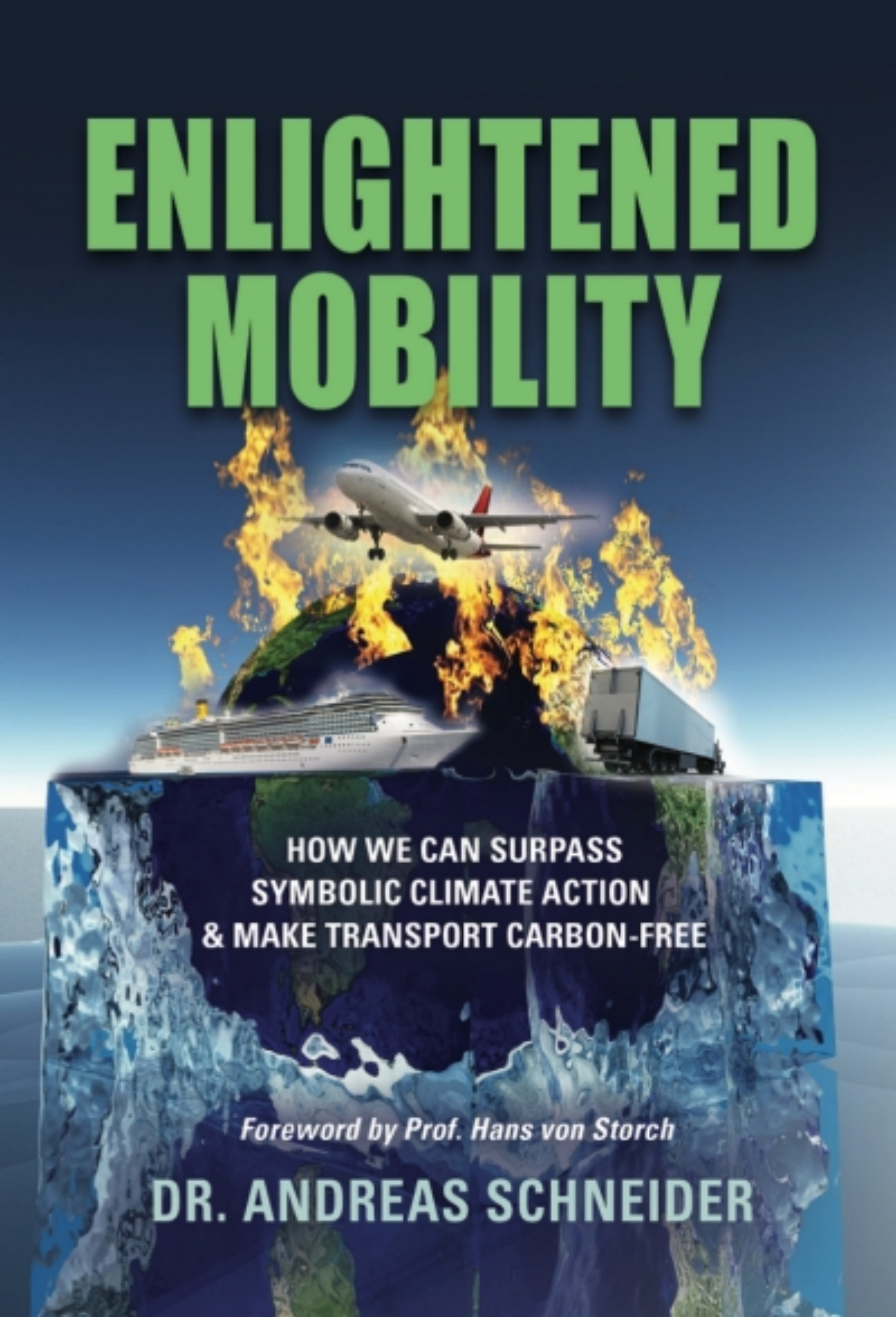
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& MAKE TRANSPORT CARBON-FREE
Foreword by Prof. Hans von Storch
DR. ANDREAS SCHNEIDER

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Table of Abbreviations

ASEAN	Association of Southeast Asian Nations
BEV	Battery-Electric Vehicle
BMS	Battery Management System
CCS	Carbon Capture and Storage
CH_4	Methane
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalents
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
DB	Deutsche Bahn
EMAL	Electromagnetic Aircraft Launch System
EU	European Union
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GT	Gigatonnes
H2	Hydrogen
HFO	Heavy Fuel Oil
HVO	Hydrotreated Vegetable Oil
ICAP	International Carbon Action Partnership
ICCT	International Council on Clean Transportation

ICE	Internal Combustion Engine
IP	Intellectual Property
IPCC	Intergovernmental Panel on Climate Change
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MaaS	Mobility-as-a-Service
MGO	Marine Gas Oil
MRT	Mass Rapid Transit
NH_3	Ammonia
PM	Particulate Matter
RCP	Representative Concentration Pathway
R&D	Research & Development
SUV	Sports Utility Vehicle
TCO	Total Cost of Ownership
TDM	Transportation Demand Management
TTP	Tank-To-Propeller
VAT	Value-Added Tax
VDMA	Verband Deutscher Maschinen- und Anlagenbau
WTT	Well-To-Tank

Introduction

Global warming and why symbolic actions won't save our climate

Believe it or not, the greenhouse effect is a good thing. It is the phenomenon by which radiation from the earth's atmosphere warms its surface to a temperature level that is higher than what it would be without this atmosphere. Without this **natural greenhouse effect**, the average temperature on earth would be at -18°C and human life would not be possible. The greenhouse effect is fueled by the greenhouse gases water vapor, carbon dioxide, methane, and ozone.[1]

The natural greenhouse effect has been enhanced by human activity since the beginning of the industrialization. This **anthropogenic greenhouse effect** can be mainly attributed to increased atmospheric carbon dioxide levels. We can notice that since the middle of the last century, **man-made global carbon dioxide emissions** have increased dramatically. In 1950, global emissions were just over 5 billion tonnes of carbon dioxide (CO_2), which is roughly the same as

[1] (IPCC, 2014)

the US, or half of China's annual emissions today. By 1990, the emissions had quadrupled to 22 billion tonnes and have continued to grow rapidly to almost 40 billion tonnes today.[2]

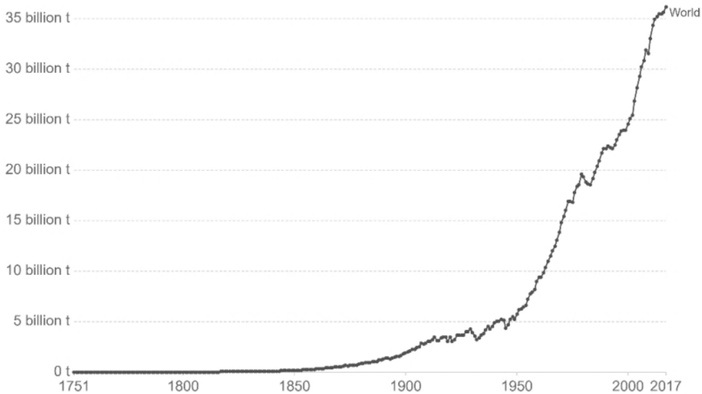

FIGURE 1: HISTORIC ANNUAL CARBON DIOXIDE EMISSIONS FROM BURNING FOSSIL FUELS
SOURCE: (RITCHIE & ROSER, 2020)

These anthropogenic (i.e., man-made) carbon dioxide emissions are a major driver of **global warming**. The warmest years globally have all occurred since 1998, with the top three being 2016, 2019 and 2015. Forecasts suggest a greater than 99% probability that most of the years between 2019 and

[2] (Ritchie & Roser, 2020)

2028 will rank within the ten warmest.[3] Historically, the globally averaged combined land and ocean surface temperature shows a warming of 0.85 °C over the period between 1880 and 2012. Several scenarios have been developed to forecast the effect of CO_2 on future temperature and sea level. In the Representative Concentration Pathway (RCP 6.0) scenario developed by the Intergovernmental Panel on Climate Change (IPCC), no additional emission mitigation efforts are taken. In this pathway, a global warming of 1.4 - 3.1 degrees Celsius relative to 1986-2005 until the end of this century is expected.[4] This warming will result in a significant sea-level rise of 0.38 to 0.73 meters higher relative to 1986-2005 which compares to a global mean sea level rise by 0.19 m over the period 1901 to 2010. A causality between increasing carbon dioxide emissions and rising temperature and sea level as well as melting polar caps has been scientifically validated.

[3] (Arguez, 2020)
[4] (IPCC, 2014)

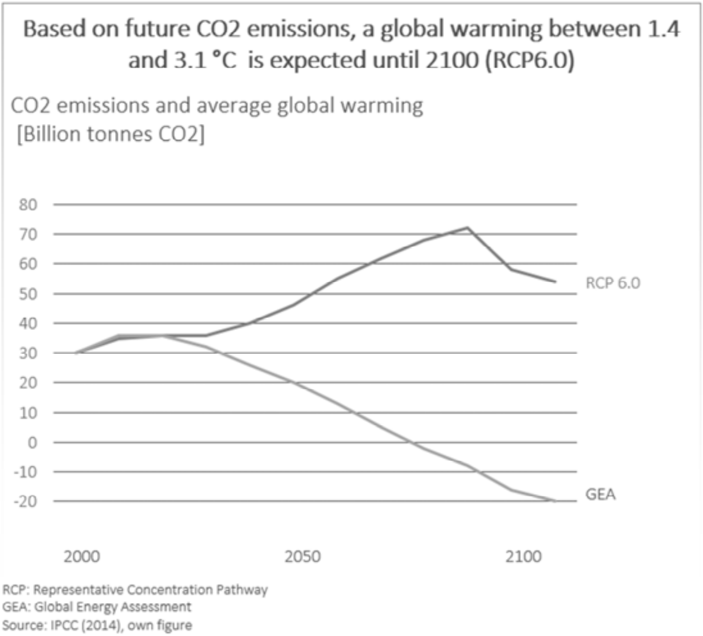

FIGURE 2: CO_2 EMISSIONS AND AVERAGE GLOBAL WARMING
SOURCE: IPCC (2014), OWN FIGURE

The findings above are proof that global warming will have severe impacts on many areas — especially several well-known cities. The Chinese city of **Shanghai**, for example, is located 4 meters above sea-level, and Malé in the Maldives only 1 meter. The impact for these cities will be dramatic, especially when considering that global mean sea level rise will probably continue for many centuries beyond 2100. "Shanghai" literally means "above the sea”. And it is hard to picture Shanghai’s promenade “The Bund” being underwater and *below the sea* in a not so far future. Higher tides are already washing away the delta soil upon which the city has been built. Forecasts assume that Shanghai will be able to handle the incremental sea level rise only until 2100. Rising sea levels with high tides, storms and flooding will put coastal cities and communities increasingly at risk. Without targeted adaptation to these rising sea levels, coastal storms and high tides will increase the frequency and severity of flooding on low-lying coasts. For some coastal cities, retreat might be inevitable.

Besides this sea-level rise, global warming has several further potentially ecological, physical and health **impacts** such as melting glaciers, droughts, storms, heatwaves, cyclones, wildfires, declining crop yields or disrupted water systems. Extreme weather conditions make cattle breeding in some regions more and more difficult. In Africa, for example, animal growth and farming productivity have dropped. In addition, carbon dioxide contributes to ocean acidification and changes to carbonate chemistry that threaten marine ecosystems such as corals.

Some research also suggests that there is an increased risk of abrupt and irreversible climate changes, the so-called **climate tipping points**. These are thresholds that, when exceeded, can lead to large discontinuities in the state of the climate system. The melting of the Greenland and Antarctic ice sheets are examples for large-scale tipping elements. On a regional level, tipping elements can be the loss of the Amazon rainforest or the collapse of the monsoon of South Asia. The melting of the Greenland ice sheet could add a further 7 meters to sea level over thousands of years. Though these tipping points might probably not be reached, the risk of disruptions has been increased. To prevent the occurrence of irreversible events and mitigate the most severe impacts of climate change, a target of keeping the global warming at **1.5°C above pre-industrial levels** has been agreed on. One way to ensure numbers remain at this level is to reduce soaring carbon dioxide emissions levels. And this reduction has to occur rapidly. Compared to a 2.0°C target, the 1.5°C target results in significant less severe impacts on ice sheets, weather extremes and biodiversity. To give an example, the Arctic Ocean will be free of ice in 10 out of 100 years for a 2.0°C warming. This compares to 1 out of 100 years for the for a 1.5°C warming. [5]

[5] (IPCC, 2018)

To achieve the aforementioned target, the focus is on **carbon dioxide** reduction. Carbon dioxide (CO_2) is one of the top contributors to Greenhouse gas (GHG) emissions, accounting for around three-quarters of all greenhouse gas emissions. In the transportation sector, these primarily come from burning fossil fuel for cars, trucks, ships, trains, and planes. CO_2 is the primary greenhouse gas emitted through human activities in transport and it is generally acceptable to focus primarily on these emissions as an indication of total GHG emissions.[6]

When it comes to limit the emission of carbon dioxide, we have seen media coverage being increasingly biased and hysteria being spurred by several climate protection groups. It is often overseen that a huge part of the discussion on how to combat climate change evolves around more or less **symbolic actions** that won't have any major impact. This is especially true for the transportation and mobility sector. Limiting long-distance air travel, prohibiting domestic flights, introducing speed limits are just a few examples of suggested actions that are supposed to save our planet.

But will prohibiting domestic flights in France significantly reduce CO_2 emissions? How about introducing a general speed limit on roads? Minor fixes won't resolve the problem.

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[6] (IDB, 2013)

If everyone had even a *rough* understanding of the facts and numbers, they would have some doubts about the attempted policies put in place. More people would know that the suggested actions are not addressing the **major levers** to reduce carbon dioxide emissions. Speed limits might be a great idea for safety reasons but they don’t reduce carbon dioxide emissions. At least not significantly. Having a look at the global carbon footprint, we need to understand that the aforementioned measures will only have a very limited, sometimes not even measurable impact. Just to make it clearer: *These actions won’t save our climate!*

So why not? And how can our measures achieve a maximum impact? What are the major levers for carbon dioxide reduction?

Country and sector views reveal the major emitters

To identify the major levers, we should have a look at the situation from two angles. On a **country level**, around 50% of global emissions are caused by the United States, China and India only. On a **sector level**, the energy sector causes about 1/3 of emissions. It is followed by transportation and mobility that accounts for about 24%.

Further detailing the emissions of the transportation sector, 75% come from passenger road (cars, motorcycles, buses, taxis) and freight road (trucks, lorries) transport, around 11% from both aviation and shipping, 1% from rail and 2% from other sources such as pipeline transport. Taking global emissions from all sectors as point of reference, all road vehicles emit 18%, air travel and ships both emit about 2.5% and roughly 1% are caused by other means of transportation (e.g., rail and pipelines).[7]

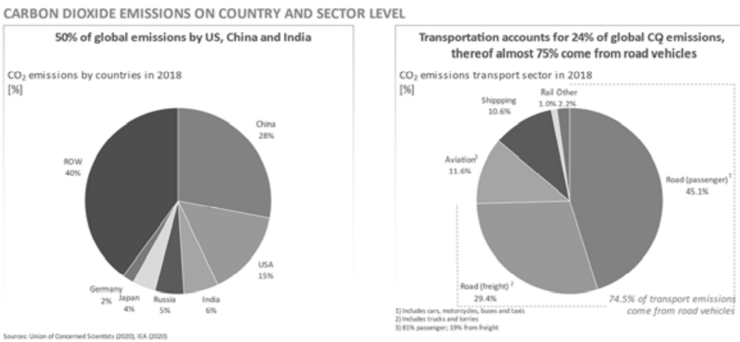


FIGURE 3: CARBON DIOXIDE EMISSIONS ON COUNTRY AND SECTOR LEVEL

SOURCES: (UNION OF CONCERNED SCIENTISTS, 2020); (IEA, 2020)

[7] (IEA, 2020)

There are two different approaches to address CO_2 reduction taking into consideration the sector- and country-level view.

Countries with the largest emissions in transportation are the United States, China, Russia and India. And the emissions are expected to further increase in the future, especially with emerging countries in Asia whose transportation sectors are growing rapidly. The strong growth rates in China, India, and other Asian economies are projected to continue over the next years, elevating millions to middle class status. The vast majority of projected carbon dioxide emissions increases are expected to come from developing Asia. In 2006, Asia accounted for 19% of total worldwide transport-related CO_2 emissions. By 2030, the share of Asia in global transport sector-related CO_2 emissions will have increased to 31%.[8] These considerations make clear how insignificant measures like prohibiting domestic flights in France or introducing a speed limit in Germany are in the global context. Their impact will even be incapable of measurement.

On **sector** level, transport is expected to become the single largest GHG emitter accounting for 46% of global emissions by 2035, and by 2050 it is set to reach 80%. These emissions in the transport sector are rising faster than in any

[8] (ADB, 2020)

other energy end-use sector. Reducing carbon emissions from transport is a challenge considering the continuing rise in demand and the slow turnover of vehicles and infrastructure in place.[9]

To not only prevent the emission growth, the transport sector will primarily need to leverage **technology and innovation**. This means that we need to develop green, carbon-neutral technologies and innovations. In the transportation and mobility field, climate-neutral technologies could be battery technology for electric cars, hydrogen-based fuel cells for trucks and aircrafts or alternative fuels for conventional cars with internal combustion engine. Moreover, we need to fully electrify our public transport (e.g., electric buses, hydrogen trains). At the same time, we will enhance digitalization and multi-modal mobility to push shared modes such as car and ride sharing connected with and to our public transport. The examples show that electrification is key to decarbonizing transport. Therefore, the transport sector is closely linked to the energy sector where the future needs to be based on renewable, carbon-neutral energy generation.

If we manage to make these technologies not only carbon-neutral but also **economically beneficial**, then these

[9] (Farrag-Thibault, 2014)

technologies will be adopted on a global scale. Even if many countries will only adopt the technologies to save cost. The economic argument is an important one since otherwise we cannot make sure that major emitting industry nations and emerging countries are following the (mostly Western) decarbonization approach. And only then the major levers are addressed.

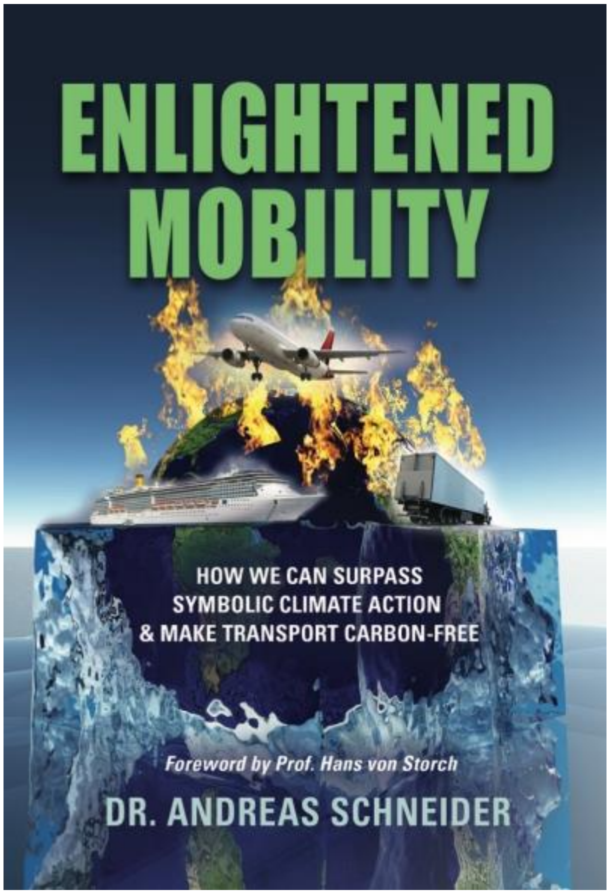
By focusing **research & development** (R&D) efforts on these technologies, their positive climate impact can be leveraged across countries and is not restricted to only limited geographies (e.g., Europe). An even further step could include an open-source approach. Being driven by a higher cause and being open-minded, our companies owning property rights such as patents could make their technologies and innovations available to the public on a global scale. This would further increase the speed of change.

These considerations make clear that stopping climate change can only work pursuing a **global approach**. Every nationalist approach is doomed to fail greatly. It can only be a joint, international effort leaving behind national short-sightedness. This does also mean that on a country level, money needs to be invested where the impact on carbon dioxide reduction for each Euro spent is the highest. Usually, money invested in developing countries results in much higher carbon dioxide reductions than the one invested in developed regions such as Central Europe or North America. In an extreme case, not switching off an efficient coal-fired power station could be a rational choice. Instead of investing in expensive green energy options to replace the efficient coal-fired plant in Europe, replacing an old coal-fired power station in Africa by a modern one can have a higher CO_2 effect per Euro invested. It is key to leave a primarily regional and country-based view and allocate resources globally to generate the highest carbon dioxide reductions possible.

This book wants to apply this more rational and less emotional mindset to outline the most beneficial strategies to combat climate change in the transportation sector. Based on the author’s experience from 15 years of consulting in the mobility and transportation field, it will strategically focus on the major levers. It will outline in which areas of transport and mobility these are, how they can be addressed and which measures need to be applied to successfully reduce the carbon footprint in the transportation sector. The goal is to strengthen our holistic thinking and to suggest a strategic approach based on facts instead of ideology.

ABOUT THE AUTHOR

Andreas Schneider is an expert, speaker and consultant in digital mobility. For more than 15 years he has been working with thought leaders in top management consulting and corporate focusing on automotive, transportation and urban mobility. He holds a Doctorate in Strategic Management from TU Clausthal and Master's degrees from Stuttgart University and Montpellier Business School. In his doctorate thesis on electric mobility, he explored innovative mobility business models. He is based in Berlin and is running the mobility blog neuemobilitaet.org.



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