NTNU Industrial Ecology

NTNU – Trondheim
Norwegian University of Science and Technology

Life cycle assessment of electric vehicles

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12TH CONCAWE SYMPOSIUM

From 20 Mar 2017 to 21 Mar 2017

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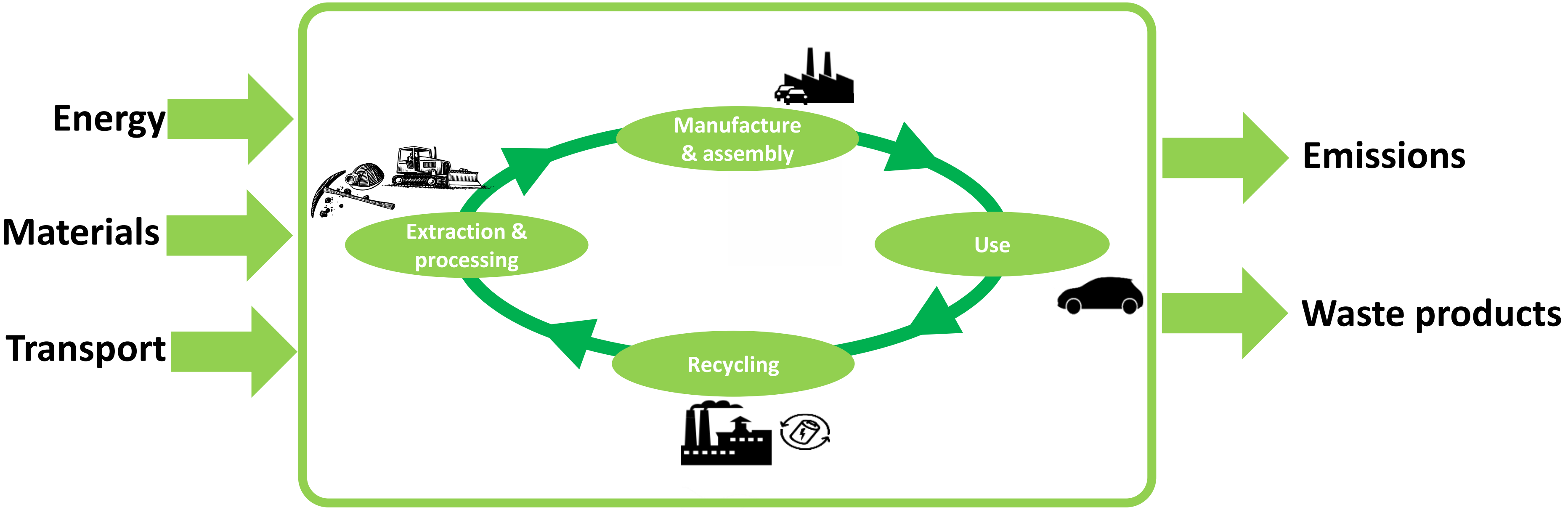
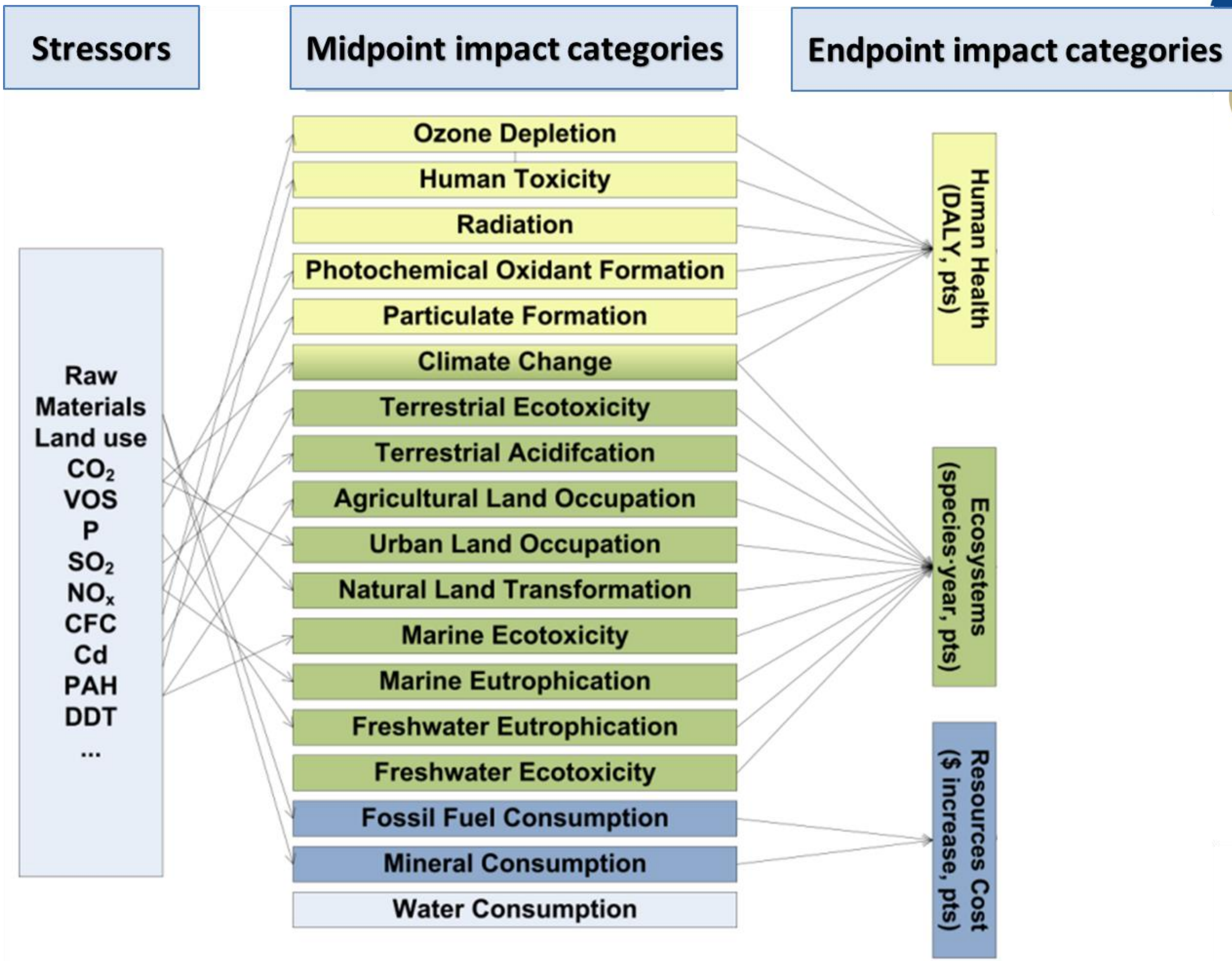
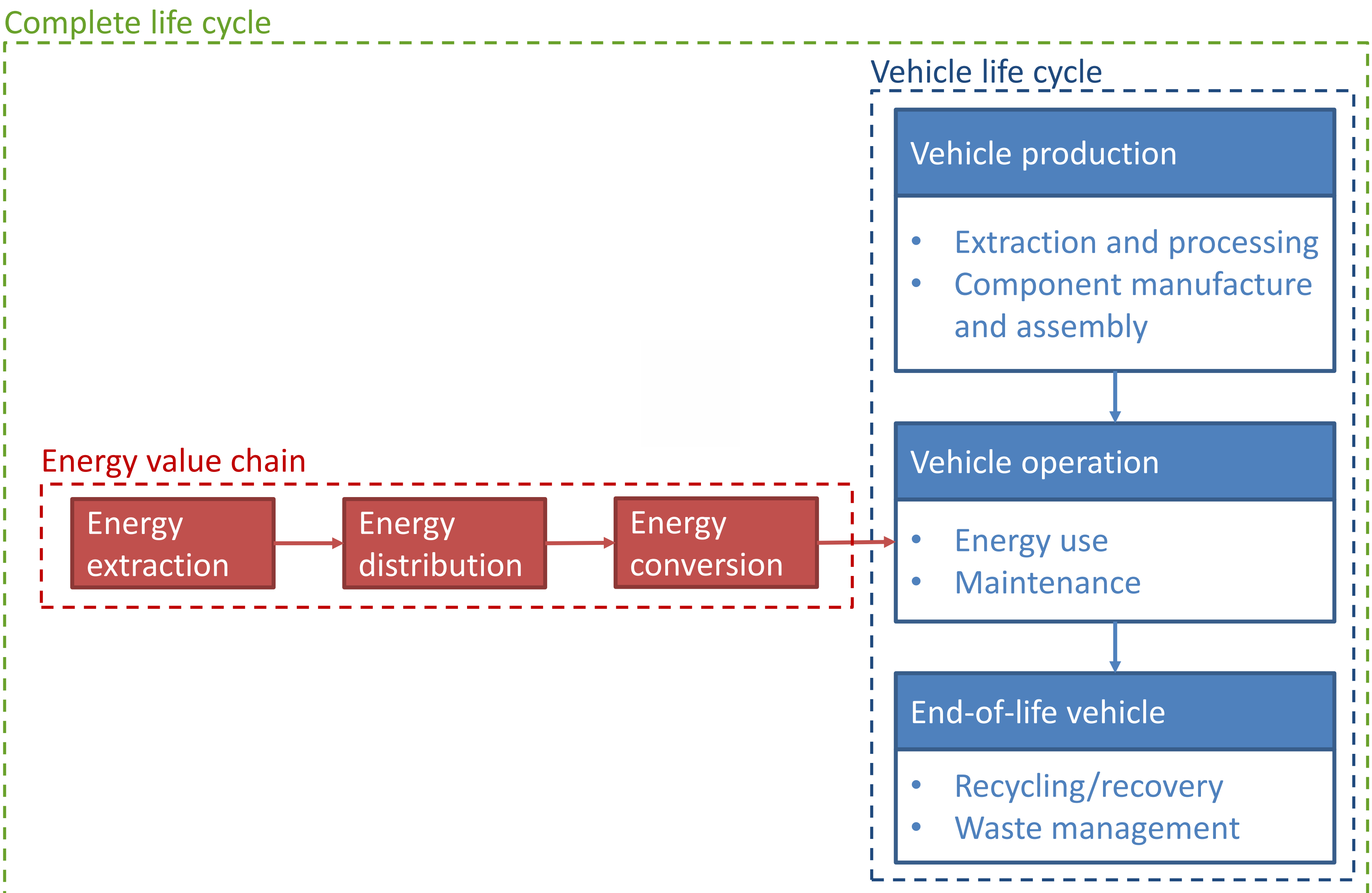
Life cycle assessment (LCA)



The ReCiPe characterization method

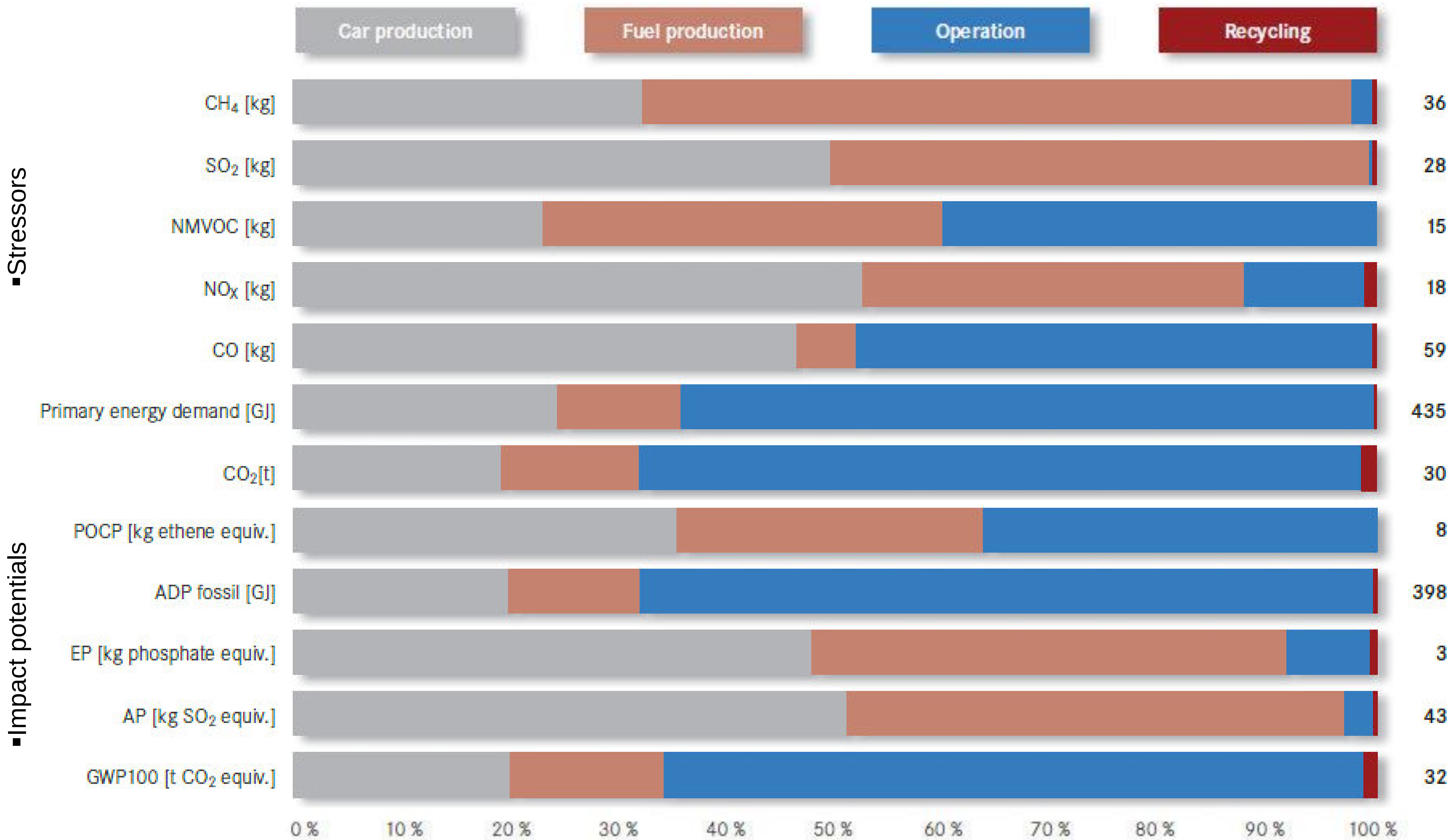


Life cycle assessment of vehicles



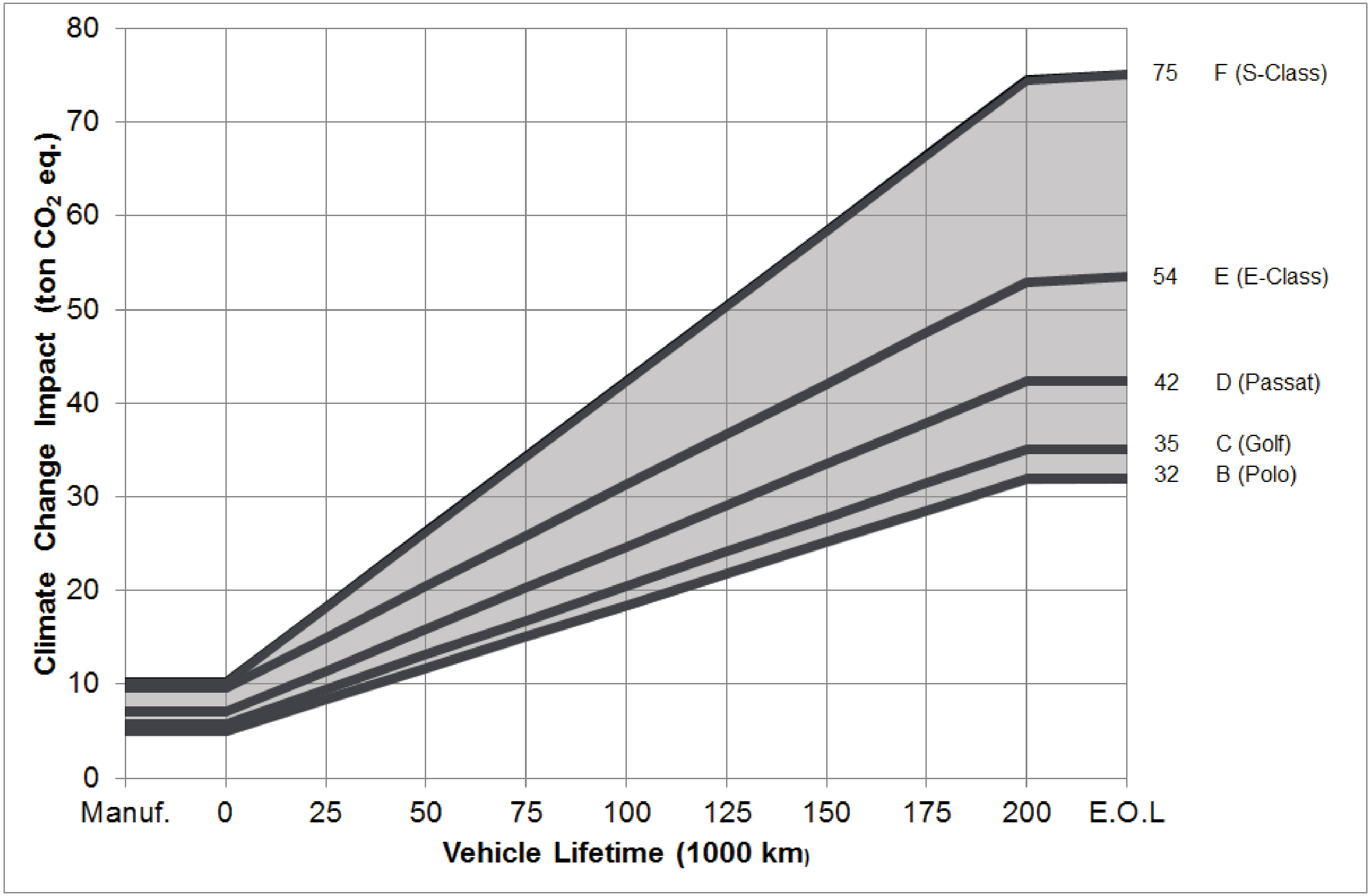
We have good knowledge of the environmental impacts of conventional vehicles

Example of typical LCA results: Mercedes A class



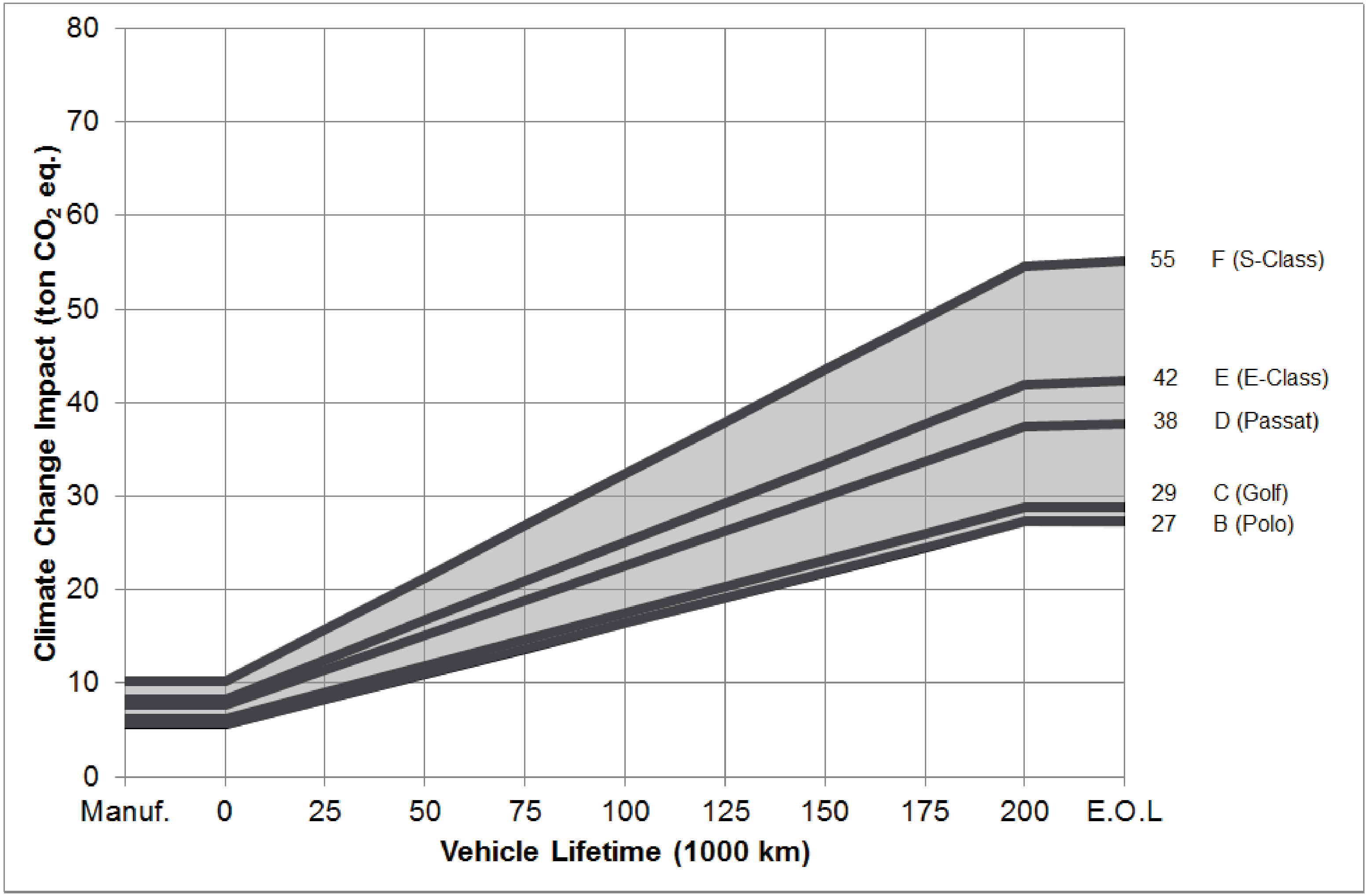
DaimlerChrysler AG, Mercedes Car Group

GHGs over the whole life cycle
- high end of the range as of 2010



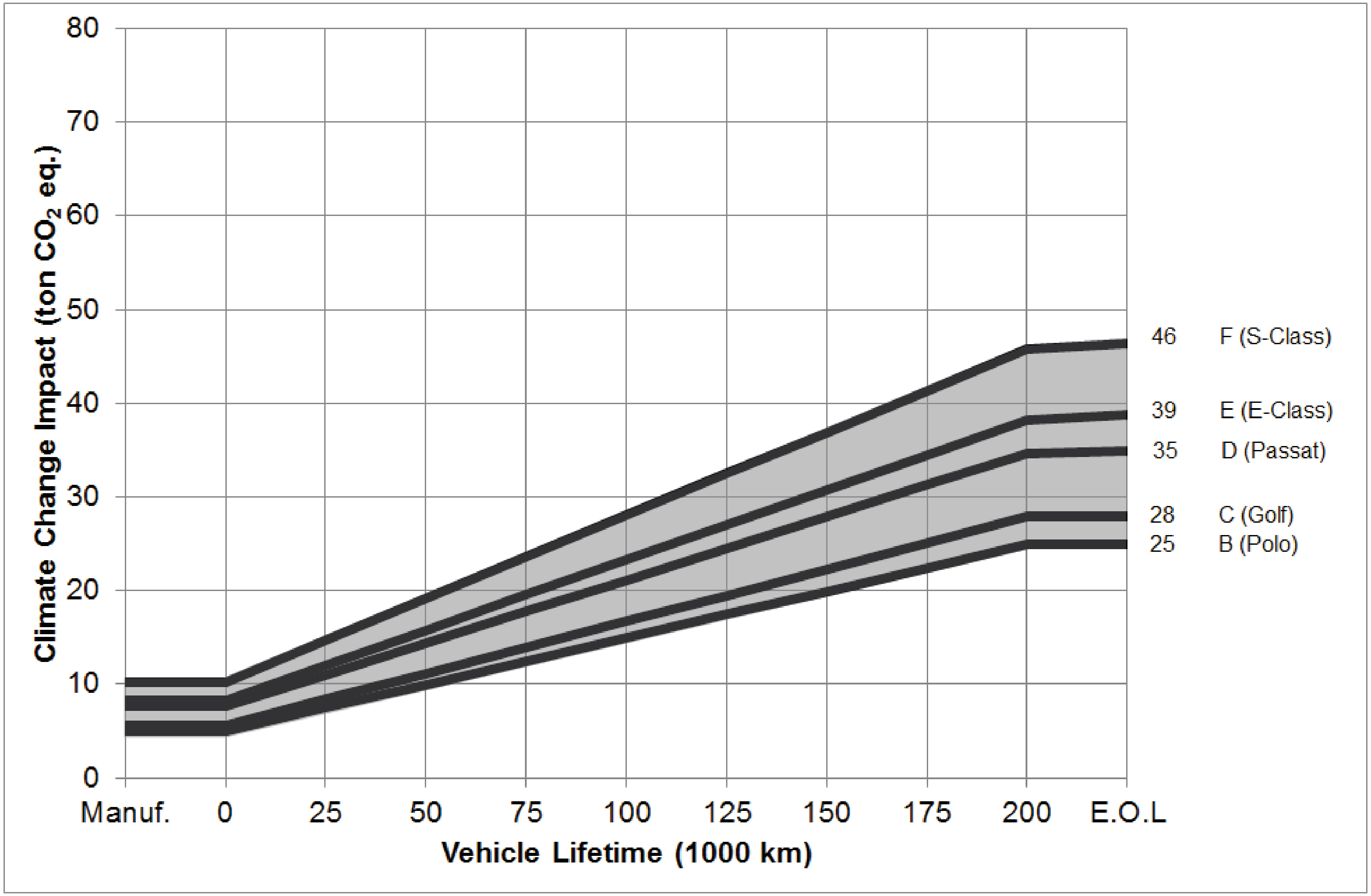
References: Daimler AG (2009, 2009, 2012), Volkswagen AG (2010, 2012)

GHGs over the whole life cycle - low end of the range as of 2010



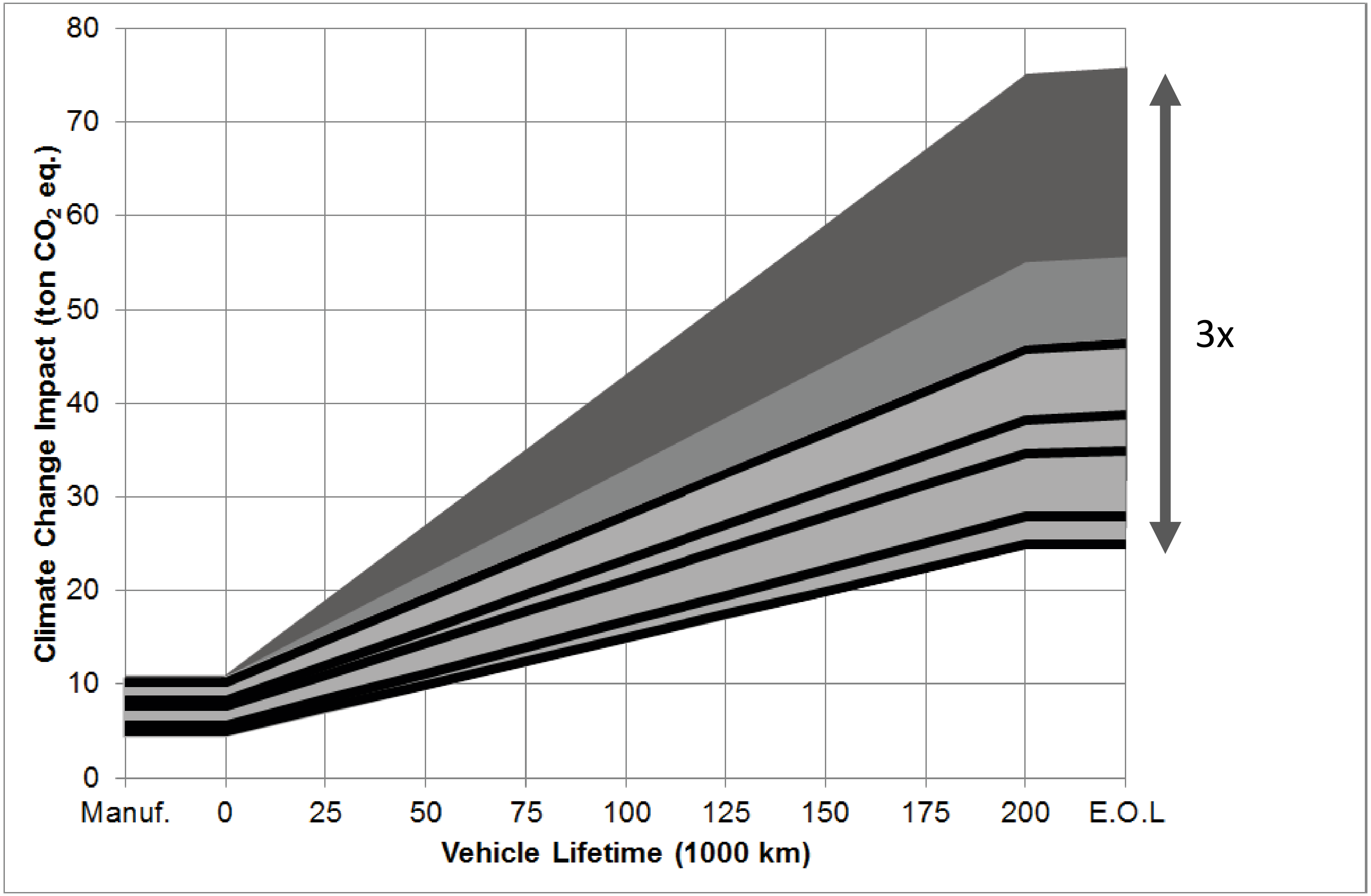
References: Daimler AG (2009, 2010, 2012,2013,2014), Volkswagen AG (2010, 2012,2013,2014)

GHGs over the whole life cycle
- low end of the range as of 2014



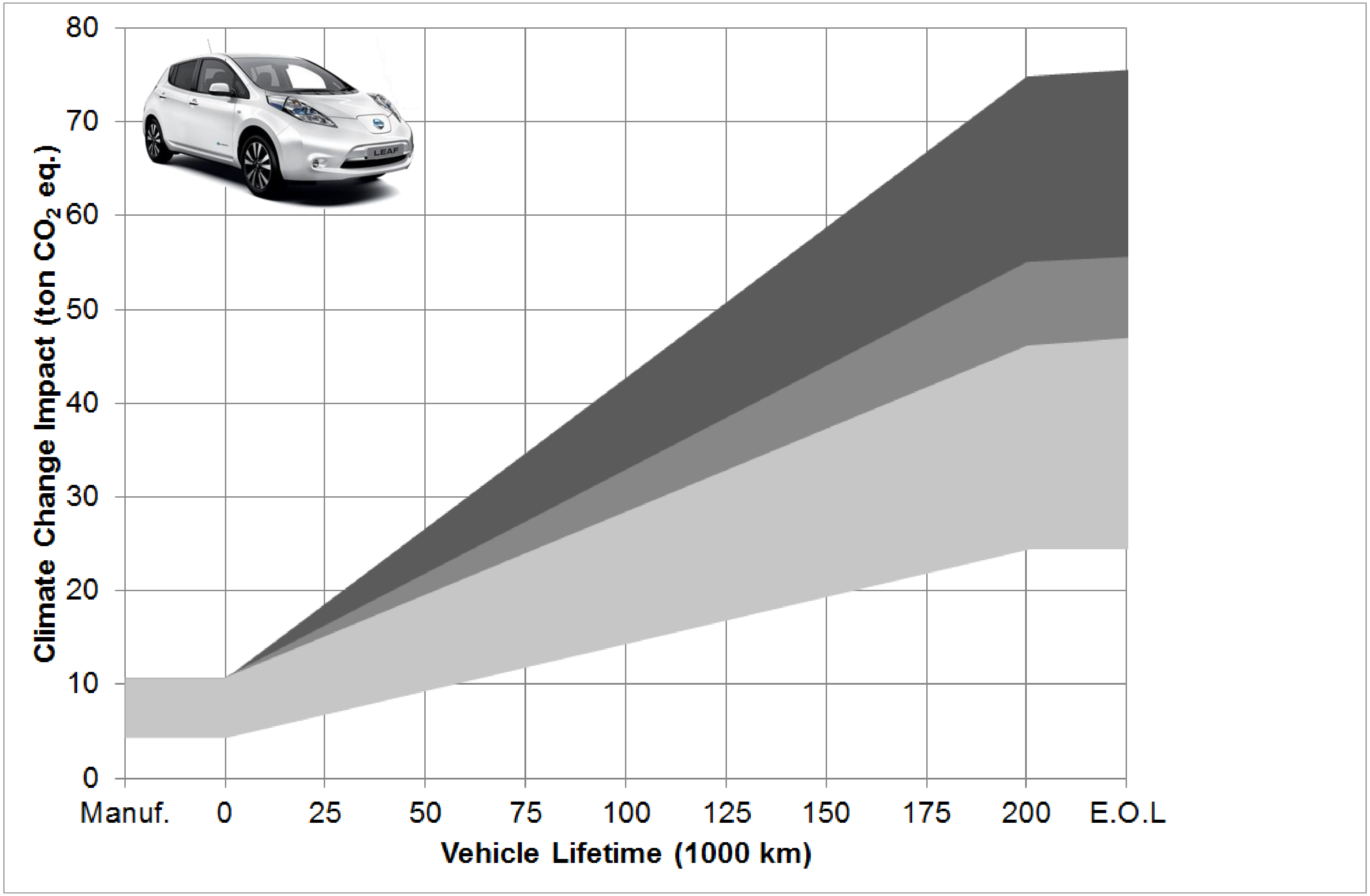
References: Daimler AG (2009, 2010, 2012,2013,2014), Volkswagen AG (2010, 2012,2013,2014)

Car size, fuel type, model year, and horsepower matter



References: Daimler AG (2009, 2010, 2012,2013,2014), Volkswagen AG (2010, 2012,2013,2014)

Can electric vehicles get us below the fossil envelope?

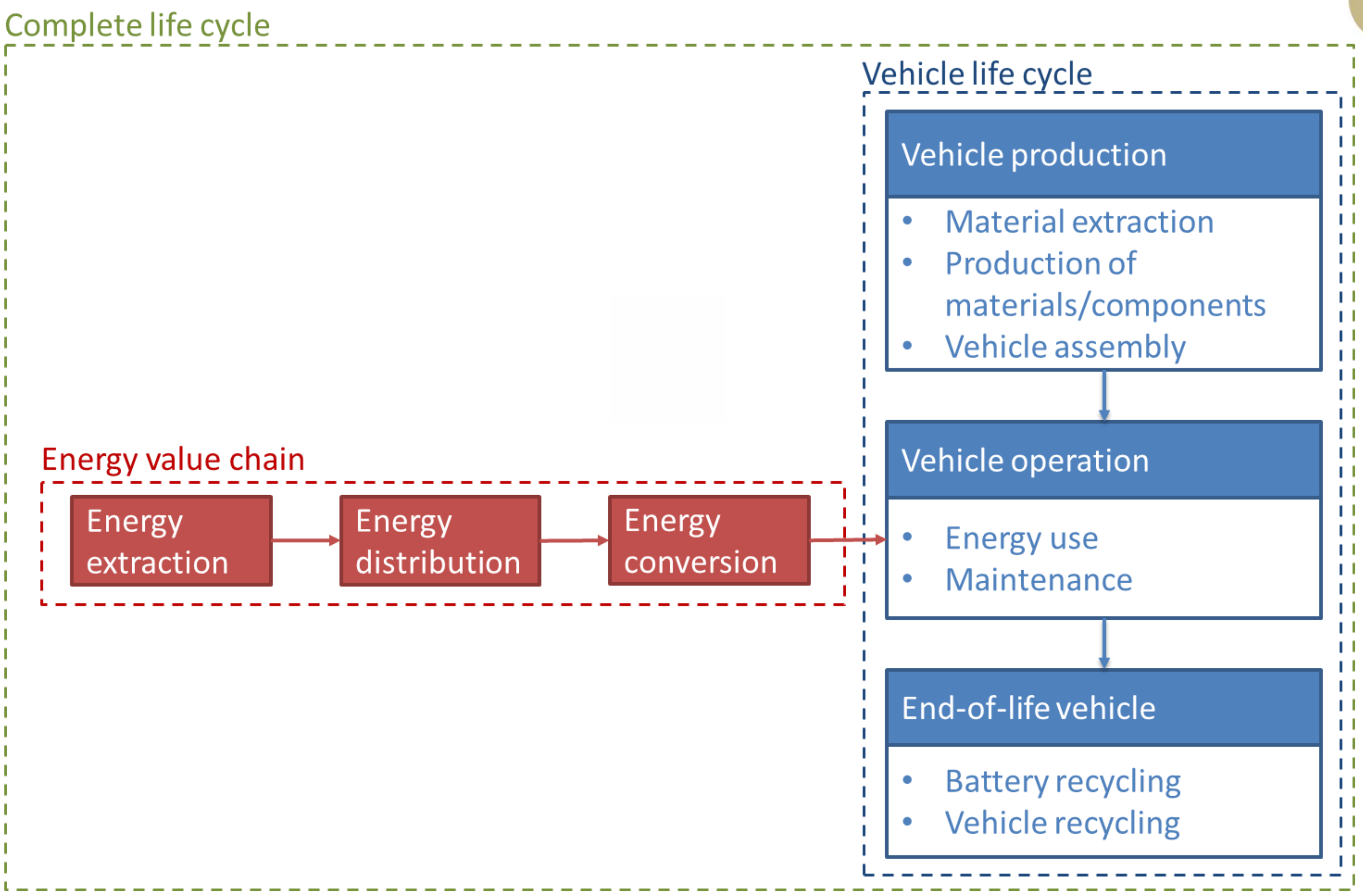


References: Daimler AG (2009, 2009, 2012,2013,2014), Volkswagen AG (2010, 2012,2013,2014)

Zero emission vehicle?

Zero Emission

BEVs have indirect operational emissions associated with the energy value chain



NTNU's latest LCA study on battery electric vehicles published in 2016

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Environmental Research Letters

LETTER • OPEN ACCESS

The size and range effect: lifecycle greenhouse gas emissions of electric vehicles

Linda Ager-Wick Ellingsen, Bhawna Singh and Anders Hammer Strømman

Published 6 May 2016 • © 2016 IOP Publishing Ltd
Environmental Research Letters, Volume 11, Number 5

Article PDF

Figures References

Figure 1.

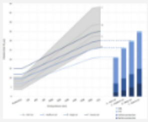


Figure 2.

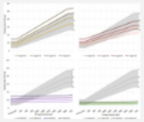


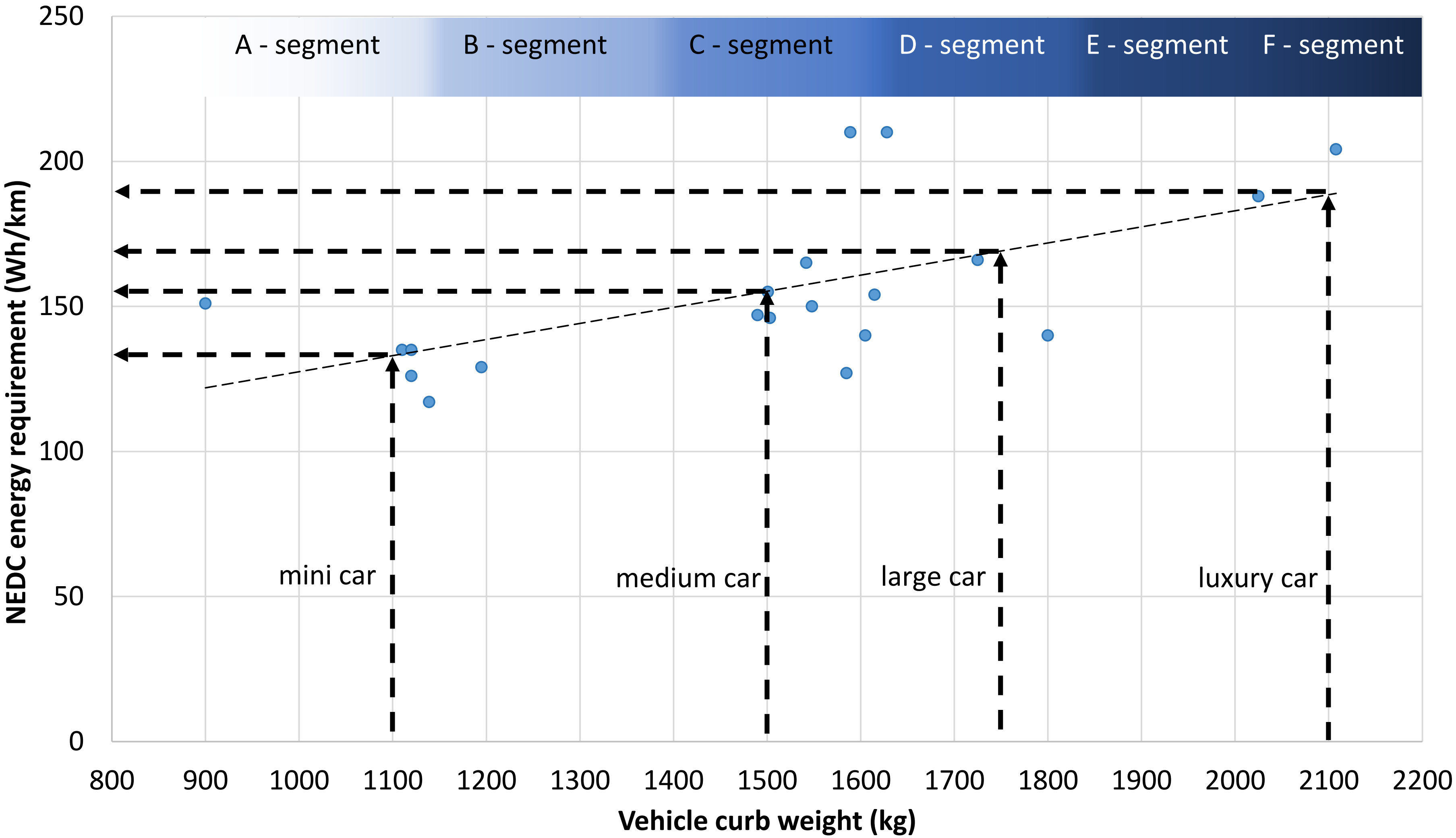
Figure 3.

Abstract

The primary goal of this study is to investigate the effect of increasing battery size and driving range to the environmental impact of electric vehicles (EVs). To this end, we compile cradle-to-grave inventories for EVs in four size segments to determine their climate change potential. A second objective is to compare the lifecycle emissions of EVs to those of conventional vehicles. For this purpose, we collect lifecycle emissions for conventional vehicles reported by automobile manufacturers. The lifecycle greenhouse gas emissions are calculated per vehicle and over a total driving range of 180 000 km using the average European electricity mix. Process-based attributional LCA and the ReCiPe characterisation method are used to estimate the climate change potential from the hierarchical perspective. The differently sized EVs are compared to one another to find the effect of increasing the size and range of EVs. We also point out the sources of differences in lifecycle emissions between conventional- and electric vehicles. Furthermore, a sensitivity analysis assesses the change in lifecycle emissions when electricity with various energy sources power the EVs. The sensitivity analysis also examines how the use phase electricity sources influences the size and range effect.

Ellingsen et al. (2016)

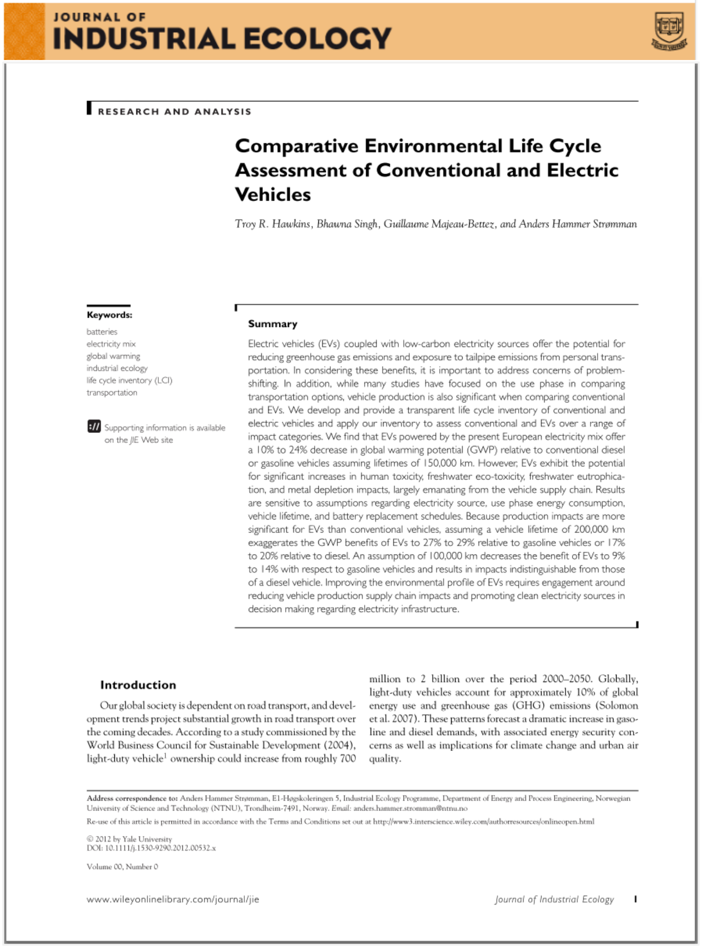
Size selection based on commercially available BEVs



Electric vehicle parameters

Segment	*Curb weight (kg)*	*Battery size (kWh)*	*Driving range (km)*	*EV energy consumption (Wh/km)*
A - mini car	1100	17.7	133	146
C - medium car	1500	26.6	171	170
D - large car	1750	42.1	249	185
F - luxury car	2100	59.9	317	207

Production inventories



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RESEARCH AND ANALYSIS

Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicles

Troy R. Hawkins, Bhawna Singh, Guillaume Majeau-Bettez, and Anders Hammer Strømman

Keywords:
batteries
electricity mix
global warming
industrial ecology
life cycle inventory (LCI)
transportation

Supporting information is available on the *JIE* Web site

Summary

Electric vehicles (EVs) coupled with low-carbon electricity sources offer the potential for reducing greenhouse gas emissions and exposure to tailpipe emissions from personal transportation. In considering these benefits, it is important to address concerns of problem-shifting. In addition, while many studies have focused on the use phase in comparing transportation options, vehicle production is also significant when comparing conventional and EVs. We develop and provide a transparent life cycle inventory of conventional and electric vehicles and apply our inventory to assess conventional and EVs over a range of impact categories. We find that EVs powered by the present European electricity mix offer a 10% to 24% decrease in global warming potential (GWP) relative to conventional diesel or gasoline vehicles assuming lifetimes of 150,000 km. However, EVs exhibit the potential for significant increases in human toxicity, freshwater eco-toxicity, freshwater eutrophication, and metal depletion impacts, largely emanating from the vehicle supply chain. Results are sensitive to assumptions regarding electricity source, use phase energy consumption, vehicle lifetime, and battery replacement schedules. Because production impacts are more significant for EVs than conventional vehicles, assuming a vehicle lifetime of 200,000 km exaggerates the GWP benefits of EVs to 27% to 29% relative to gasoline vehicles or 17% to 20% relative to diesel. An assumption of 100,000 km decreases the benefit of EVs to 9% to 14% with respect to gasoline vehicles and results in impacts indistinguishable from those of a diesel vehicle. Improving the environmental profile of EVs requires engagement around reducing vehicle production supply chain impacts and promoting clean electricity sources in decision making regarding electricity infrastructure.

Introduction

Our global society is dependent on road transport, and development trends project substantial growth in road transport over the coming decades. According to a study commissioned by the World Business Council for Sustainable Development (2004), light-duty vehicle[1] ownership could increase from roughly 700 million to 2 billion over the period 2000–2050. Globally, light-duty vehicles account for approximately 10% of global energy use and greenhouse gas (GHG) emissions (Solomon et al. 2007). These patterns forecast a dramatic increase in gasoline and diesel demands, with associated energy security concerns as well as implications for climate change and urban air quality.

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© 2012 by Yale University
DOI: 10.1111/j.1530-9290.2012.00532.x

Volume 00, Number 0

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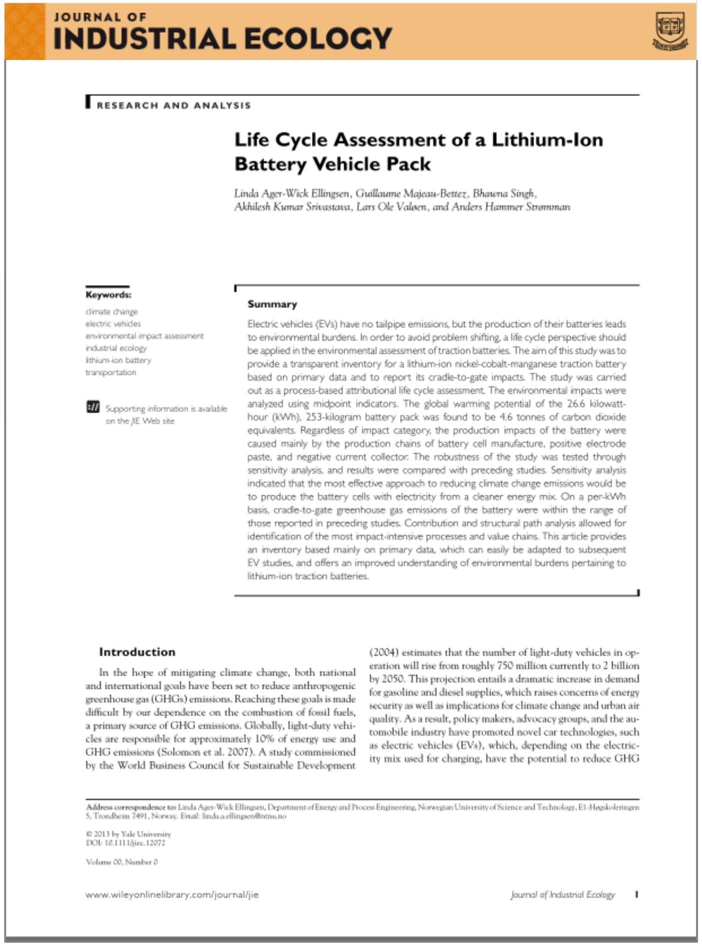

JOURNAL OF
INDUSTRIAL ECOLOGY

RESEARCH AND ANALYSIS

Life Cycle Assessment of a Lithium-Ion Battery Vehicle Pack

Linda Ager-Wick Ellingsen, Guillaume Majeau-Bettez, Bhawna Singh, Akhilesh Kumar Srivastava, Lars Ole Valøen, and Anders Hammer Strømman

Keywords:
climate change
electric vehicles
environmental impact assessment
industrial ecology
lithium-ion battery
transportation

Supporting information is available on the *JIE* Web site

Summary

Electric vehicles (EVs) have no tailpipe emissions, but the production of their batteries leads to environmental burdens. In order to avoid problem shifting, a life cycle perspective should be applied in the environmental assessment of traction batteries. The aim of this study was to provide a transparent inventory for a lithium-ion nickel-cobalt-manganese traction battery based on primary data and to report its cradle-to-gate impacts. The study was carried out as a process-based attributional life cycle assessment. The environmental impacts were analyzed using midpoint indicators. The global warming potential of the 26.6 kilowatt-hour (kWh), 253-kilogram battery pack was found to be 4.6 tonnes of carbon dioxide equivalents. Regardless of impact category, the production impacts of the battery were caused mainly by the production chains of battery cell manufacture, positive electrode paste, and negative current collector. The robustness of the study was tested through sensitivity analysis, and results were compared with preceding studies. Sensitivity analysis indicated that the most effective approach to reducing climate change emissions would be to produce the battery cells with electricity from a cleaner energy mix. On a per-kWh basis, cradle-to-gate greenhouse gas emissions of the battery were within the range of those reported in preceding studies. Contribution and structural path analysis allowed for identification of the most impact-intensive processes and value chains. This article provides an inventory based mainly on primary data, which can easily be adapted to subsequent EV studies, and offers an improved understanding of environmental burdens pertaining to lithium-ion traction batteries.

Introduction

In the hope of mitigating climate change, both national and international goals have been set to reduce anthropogenic greenhouse gas (GHGs) emissions. Reaching these goals is made difficult by our dependence on the combustion of fossil fuels, a primary source of GHG emissions. Globally, light-duty vehicles are responsible for approximately 10% of energy use and GHG emissions (Solomon et al. 2007). A study commissioned by the World Business Council for Sustainable Development (2004) estimates that the number of light-duty vehicles in operation will rise from roughly 750 million currently to 2 billion by 2050. This projection entails a dramatic increase in demand for gasoline and diesel supplies, which raises concerns of energy security as well as implications for climate change and urban air quality. As a result, policy makers, advocacy groups, and the automobile industry have promoted novel car technologies, such as electric vehicles (EVs), which, depending on the electricity mix used for charging, have the potential to reduce GHG

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DOI: 10.1111/jiec.12072

Volume 00, Number 0

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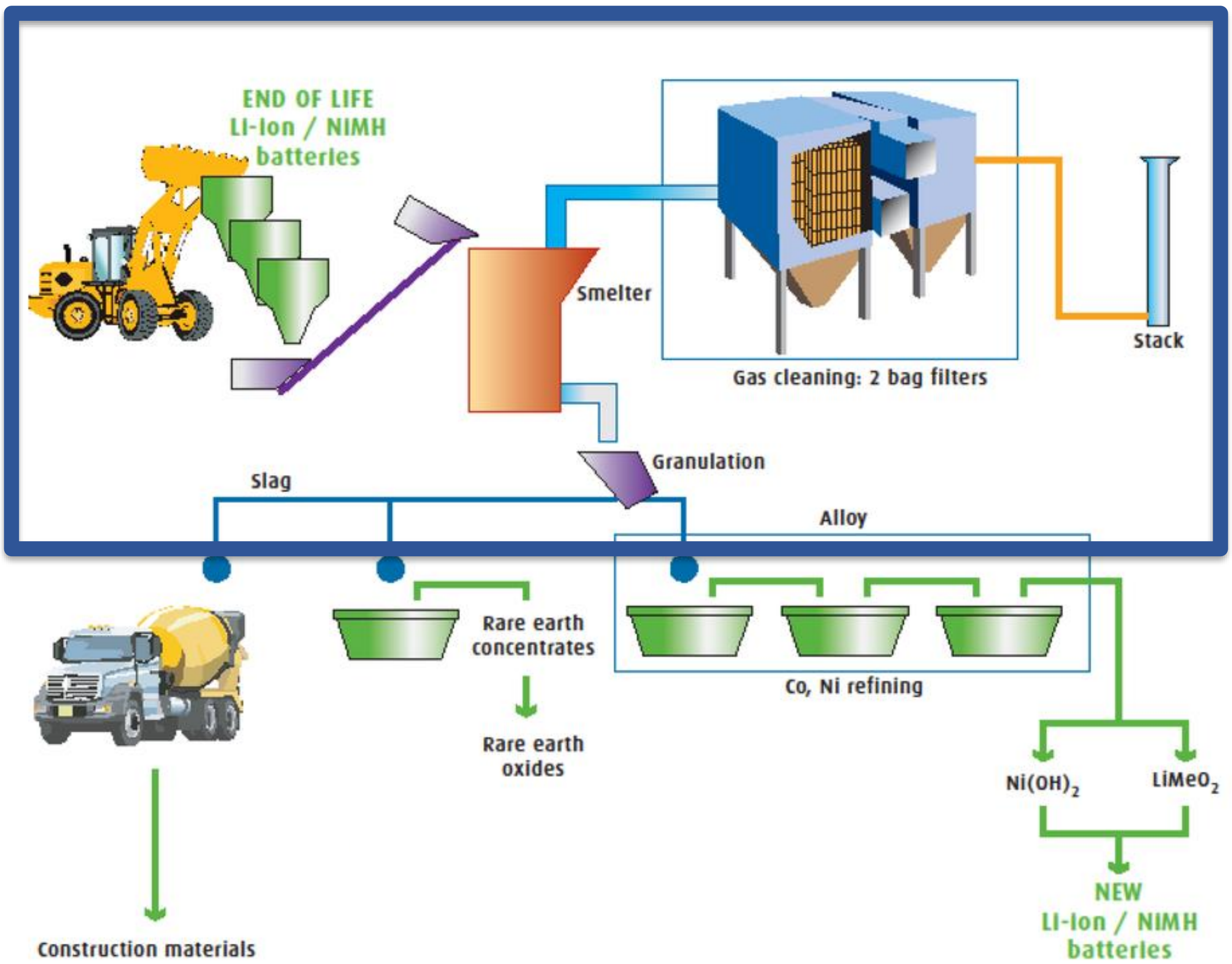
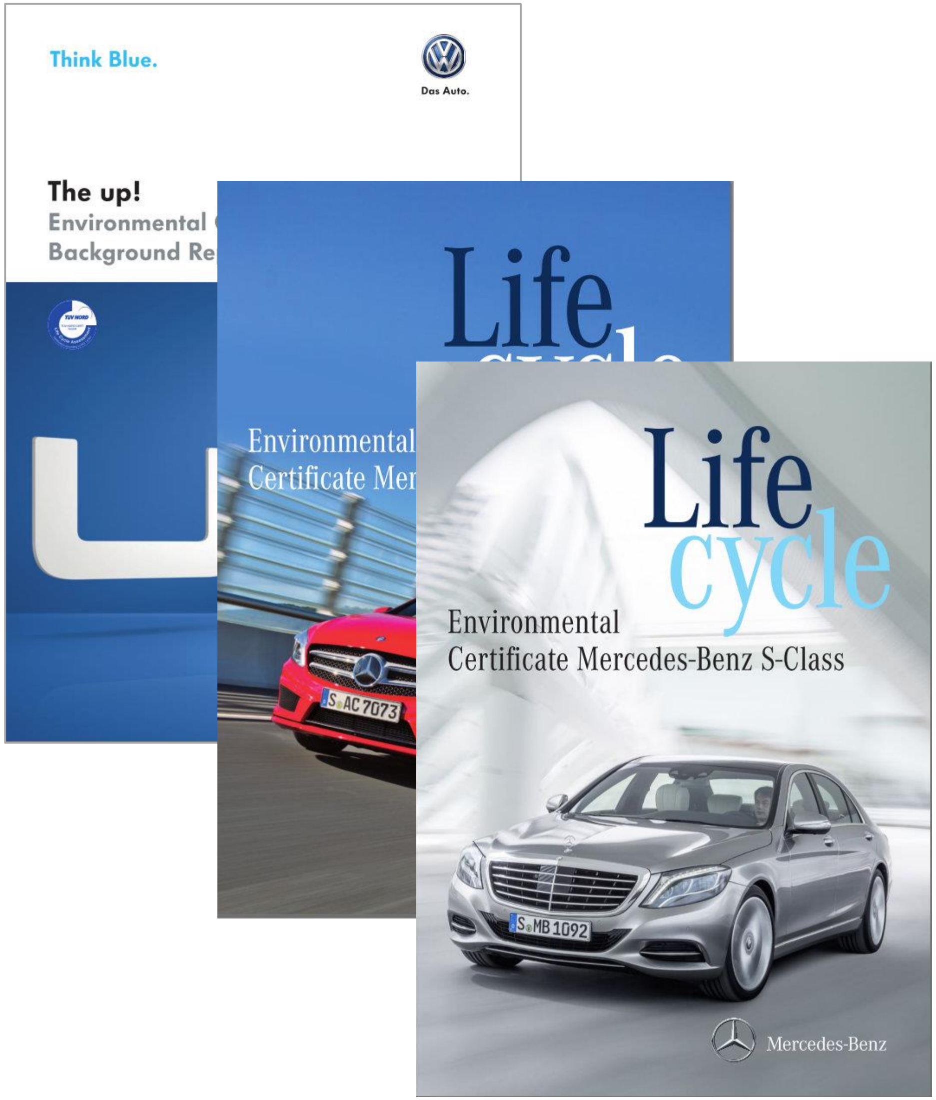
Use phase assumptions

- Average European electricity mix (521 g CO_2/kWh at plug, 462 g CO_2/kWh at plant)
- 12 years and a yearly mileage of 15,000 km, resulting in a total mileage of 180,000 km

End-of-life treatment

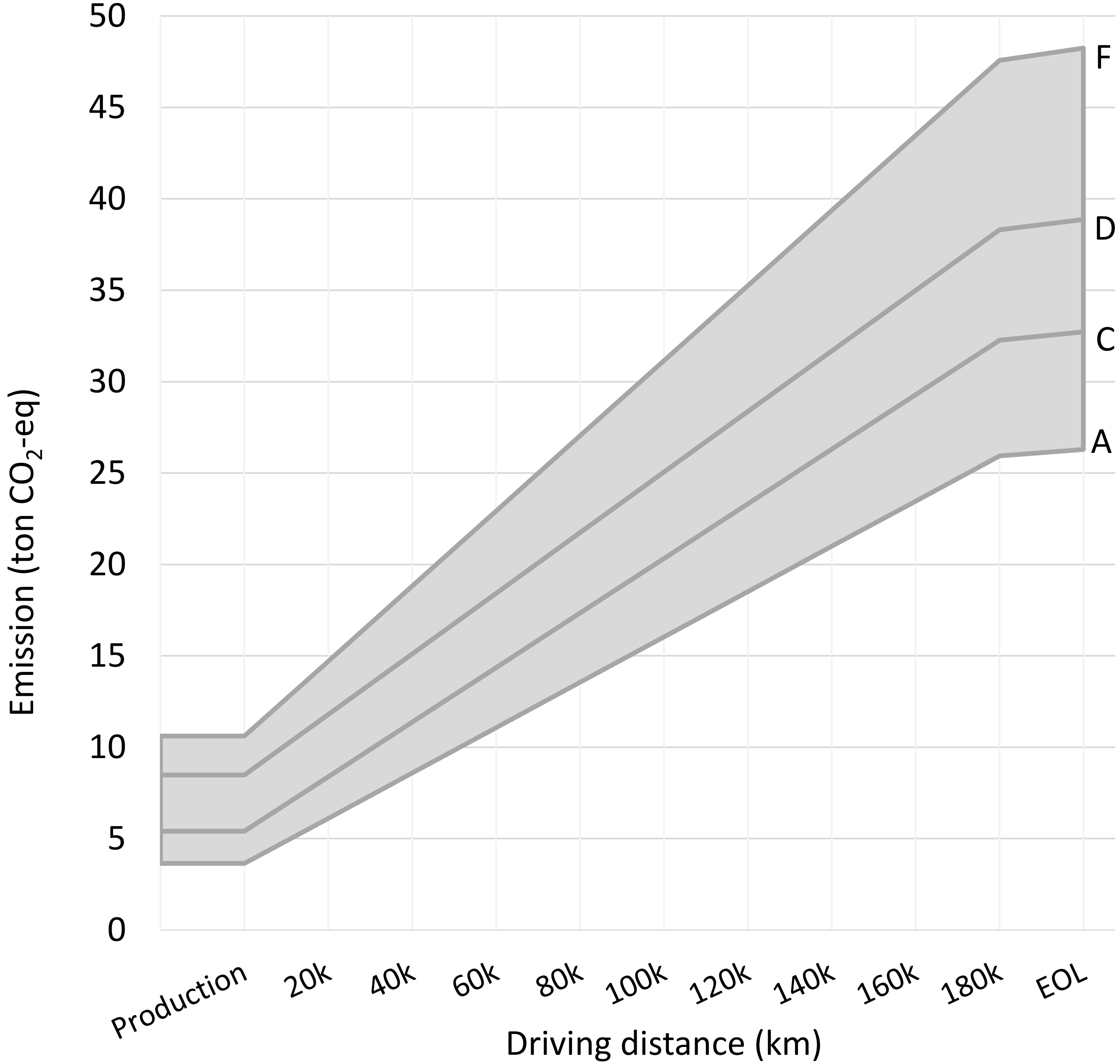


Conventional vehicles



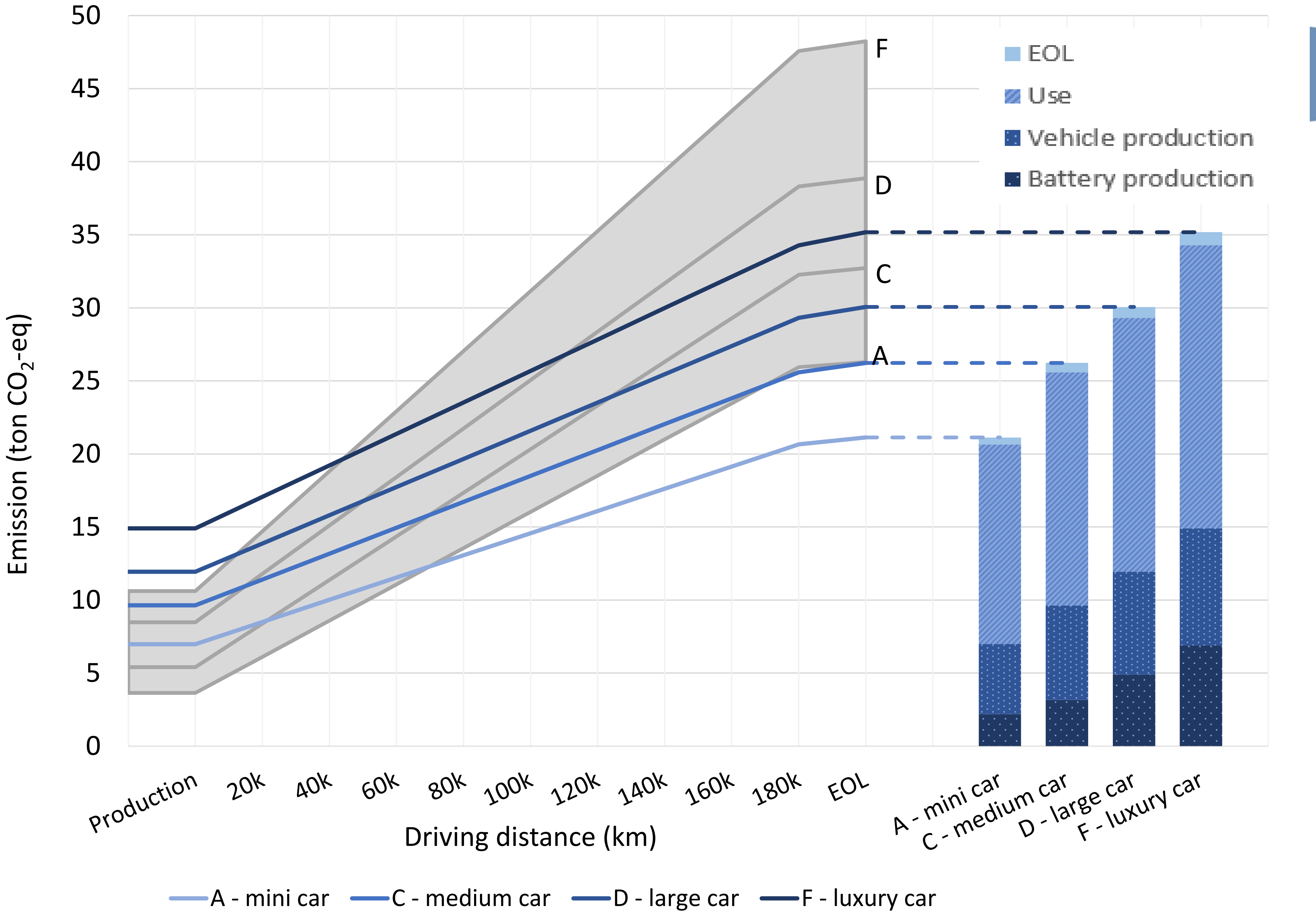
- Production and use phase from LCA reports
- End-of-life inventory from Hawkins et al. 2012

Results



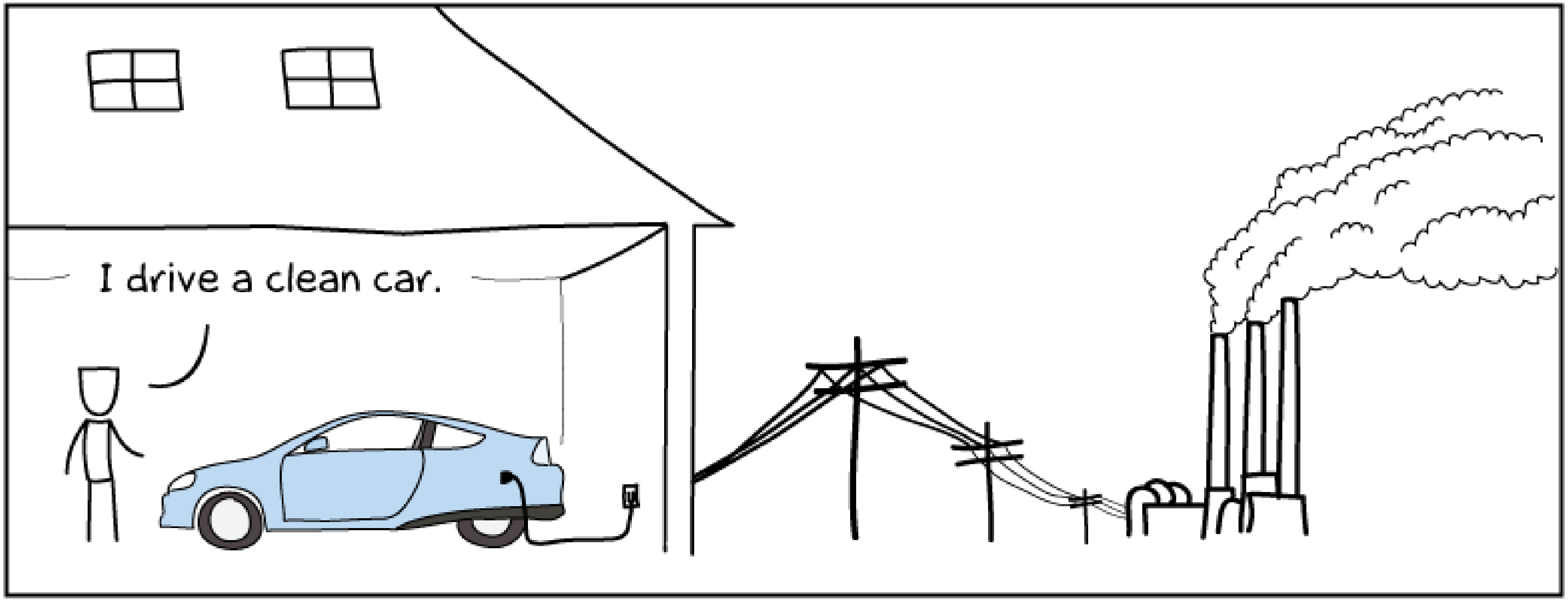
Fossil envelope
-average new ICEVs as of 2015

Ellingsen et al. 2016

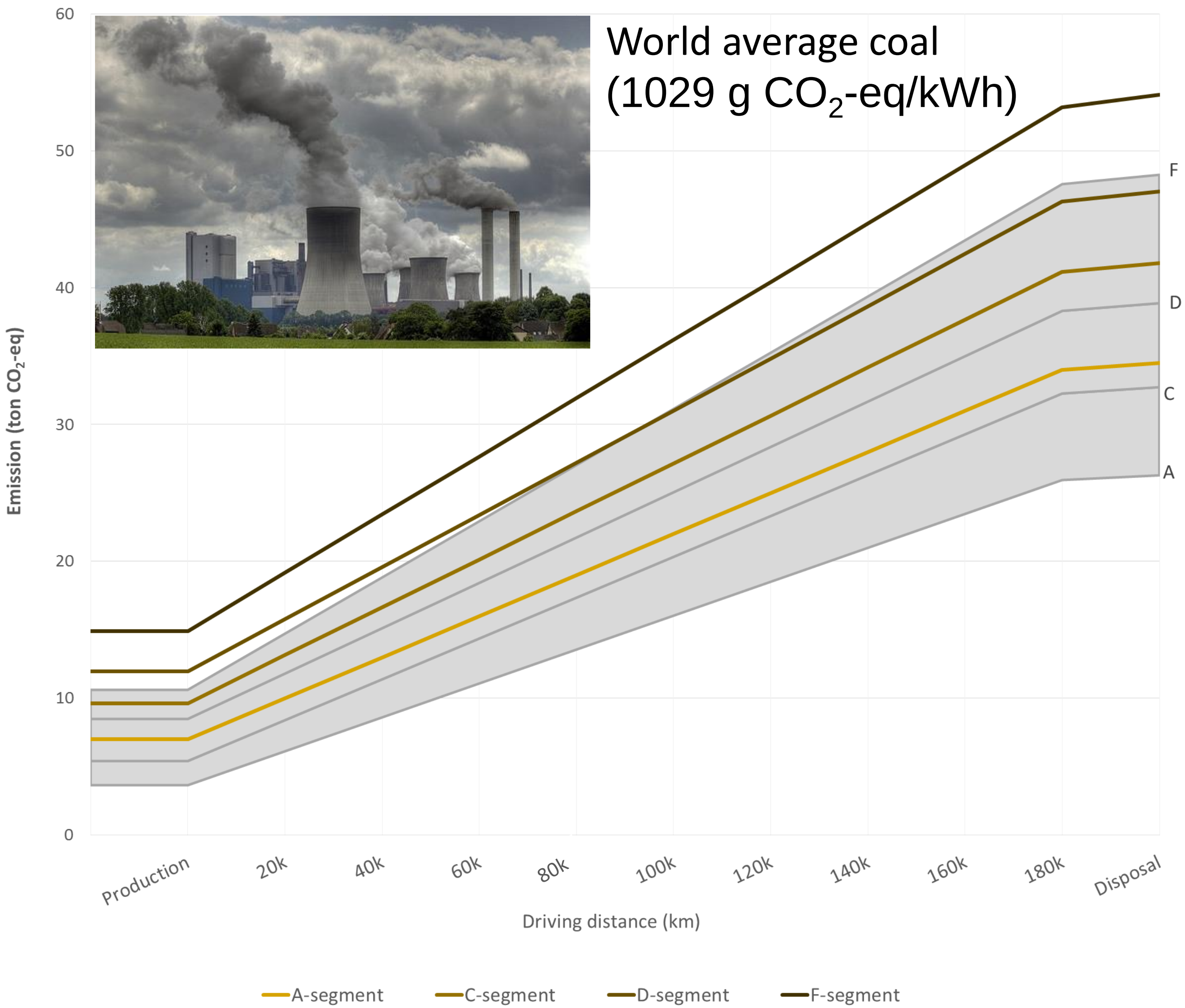


Ellingsen et al. 2016

Sensitivity analysis



Sensitivity analysis - coal



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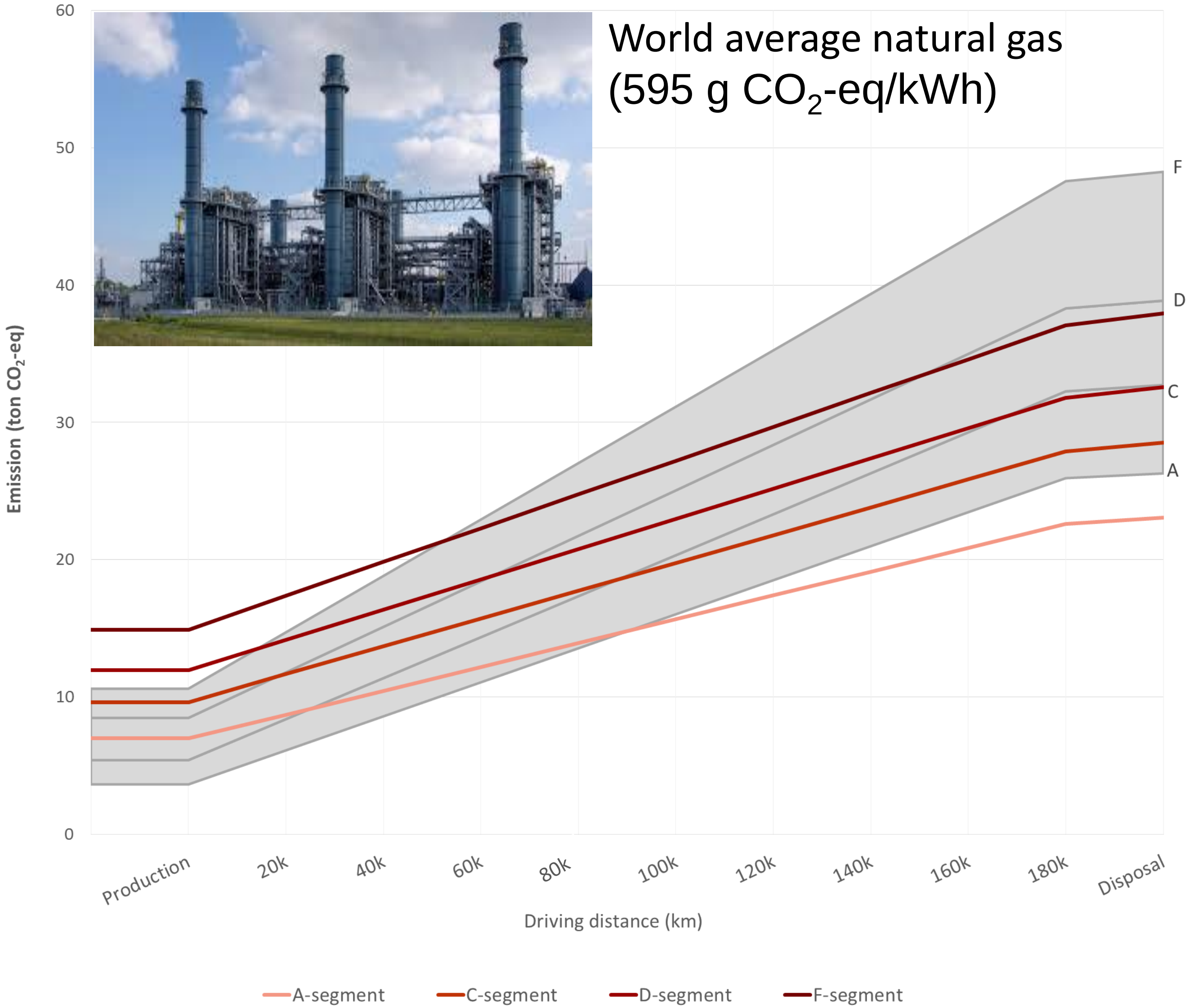
Sensitivity analysis – natural gas



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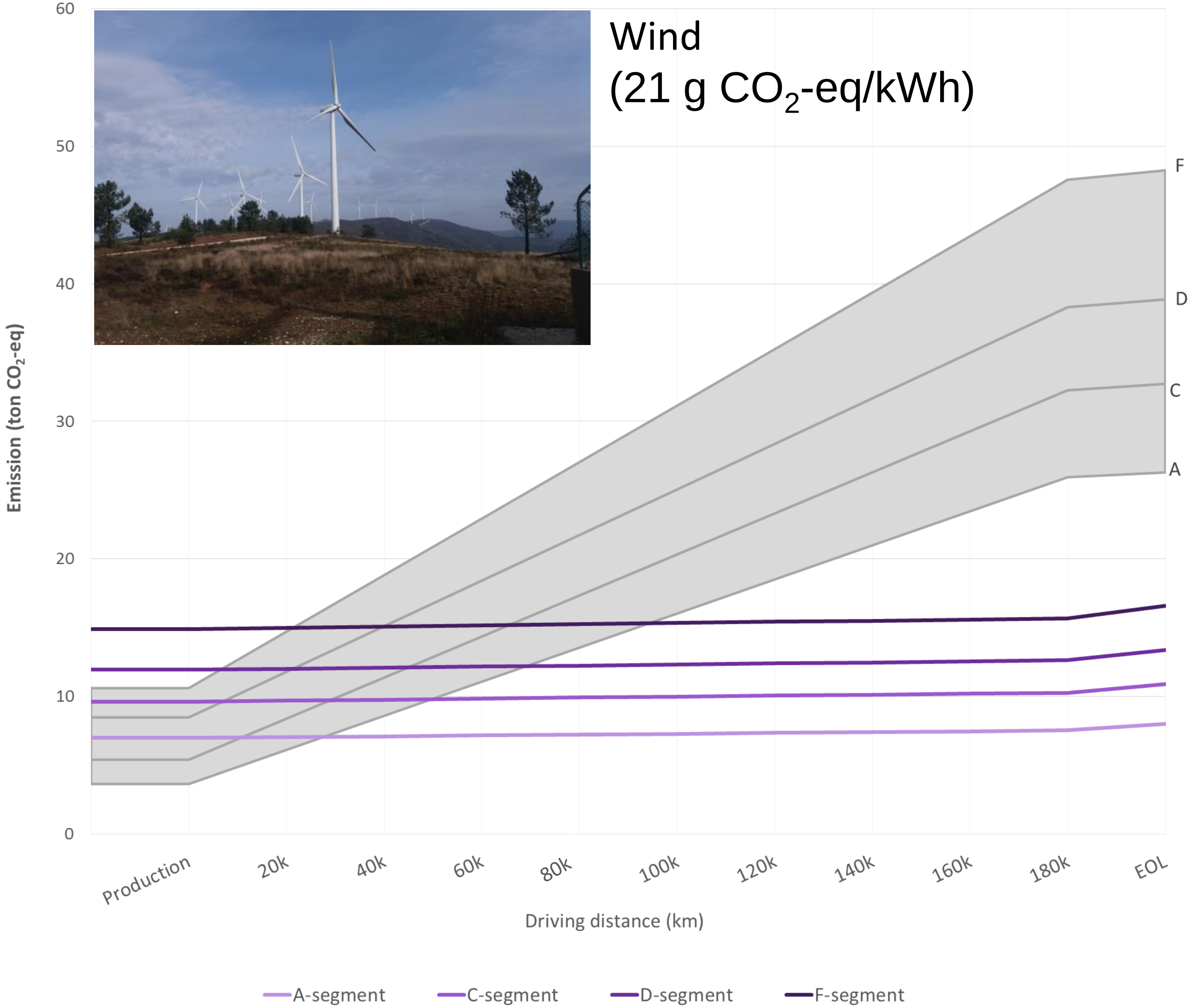
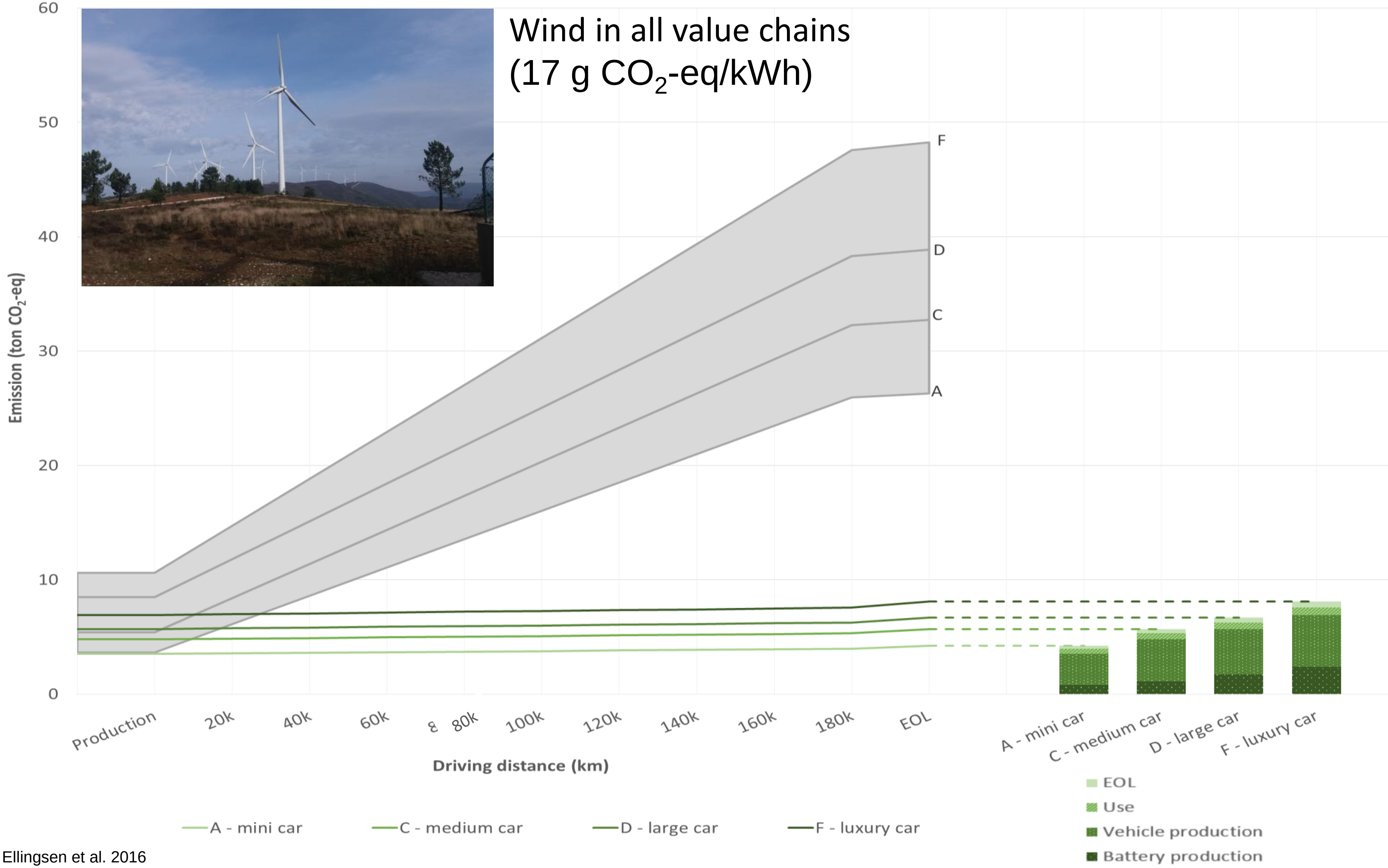
Sensitivity analysis – wind



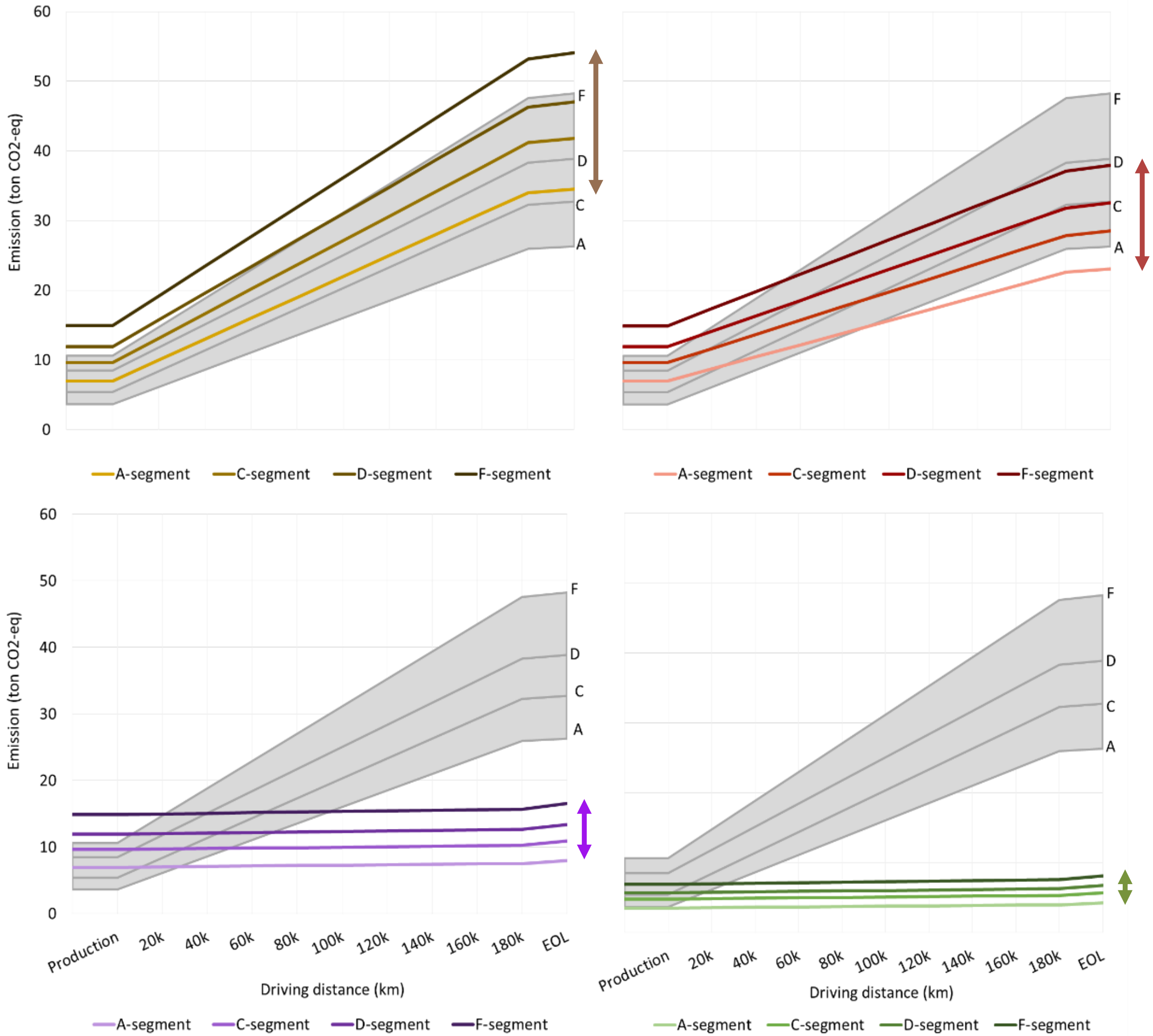
Ellingsen et al. 2016

Sensitivity analysis – all wind



Ellingsen et al. 2016

Differences in emissions due to size decrease with lower carbon intensity



Ellingsen et al. 2016

Questions?

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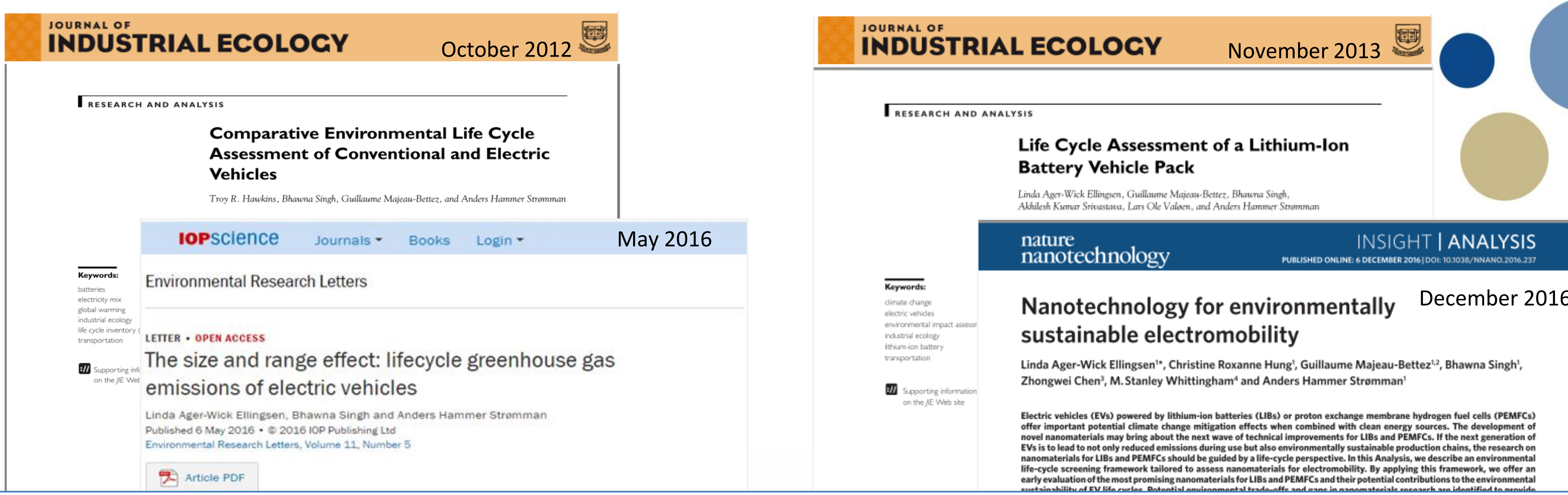

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Majeau-Bettez, M., Hawkings, T., & Strømman, A. H. (2011) Life Cycle Environmental Assessment of Lithium-ion and Nickel Metal Hydride Batteries for Plug-in Hybrid and Battery Electric Vehicles