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Life Cycle Assessment on Electric Cargo Bikes for the Use-Case of Urban Freight Transportation in Ghana

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Agenda

1. **Problem Statement & Research Questions**
   Environmental challenges for Mobility in Ghana

2. **Methodology**
   Life Cycle Assessment and Analysis of the Ghanian Modal Split

3. **Results**
   Greenhouse Gas Emission Balance with different scenarios and Reduction Potentials

4. **Discussion and Conclusion**

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Problem statement and Research question

Environmental challenges for mobility in Ghana

- Ghana is experiencing an economic and population boom that causes increasing numbers of cars and mopeds on the road resulting in rising environmental pollution
- In 2015, 6,819 Mt CO_2 were emitted by the transportation sector in Ghana, accounting for 25% of all CO_2 emissions.
- The growth in transportation emissions is averaging 11.1% per year
- Mobility alternatives with low greenhouse gas emissions are needed to reduce the emissions balance of the transport sector in Ghana. E-cargo bikes were identified as a possible emission-saving alternative, but the reduction potential for the region is not known.

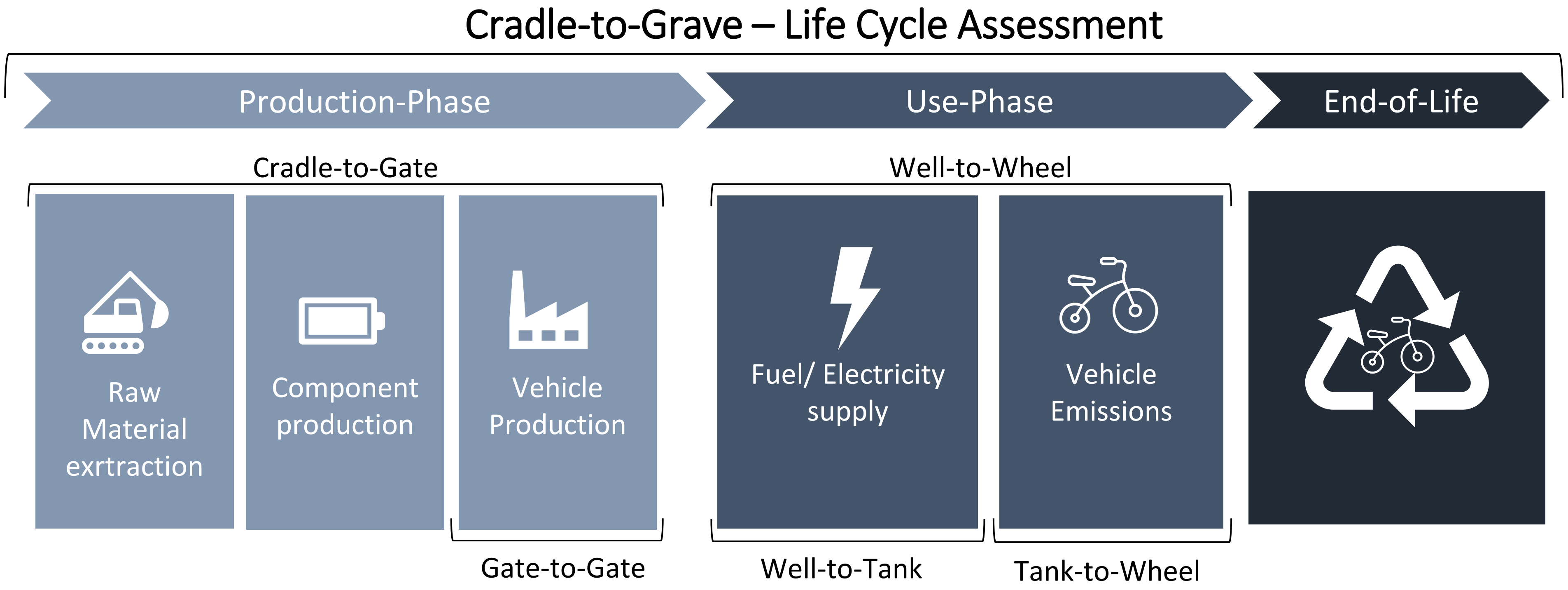
→ How many greenhouse gas emissions can be saved by using e-cargo bikes in urban areas in Ghana?

Source: [1][2]

Picture top: Map Ghana from https://www.britannica.com/place/Ghana; Pictures middle: Busy streets in Ghana taken by F. Adjei; Picture bottom: Analysed e-cargo bike taken by manufacturer

Methodology: Life Cycle Assessment (LCA)

Goal and scope



Own illustration based on DIN EN ISO 14044:2018-05.

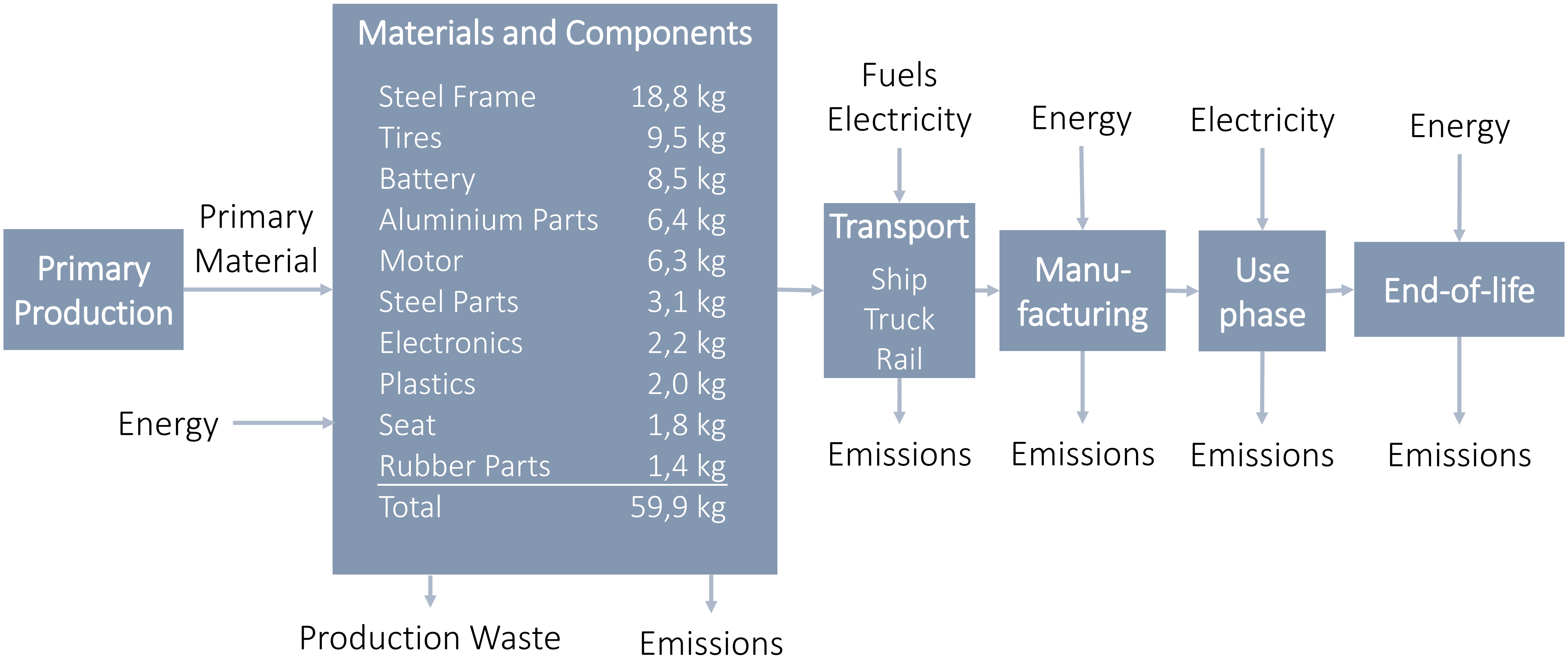
Impact category: Global Warming Potential, 100 years (GWP100) in CO_2-equivalents, (CO_2e)

Functional unit: 1 ton-kilometer (tkm)

Sources: [3][4][5]

Methodology

System boundaries and life cycle inventory



System Boundaries for the LCA of the analysed e-cargo bike. Own illustration.

Methodology

Description of the scenarios

Production: Lifetime + country of origin

- Battery (48 V/20 AH): 4 years China
- Electronics + engine: 10 years China
- Tires: 6 years Japan
- Bike Frame + rest: 20 years Finland and Germany

Transportation

Components from country of origin to Germany and finished e-cargo bike from Germany to Ghana with containership, rail and truck

Manufacturing

Including electricity and gas for welding in Germany

Use

- Scenario 1: Charing with photovoltaic
- Scenario 2: Charing with the Ghanian national grid

End-of-life: Shredding

Battery charging cycles and electricity consumption

1000 charging cycles / battery
1,1 kWh / charging cycle

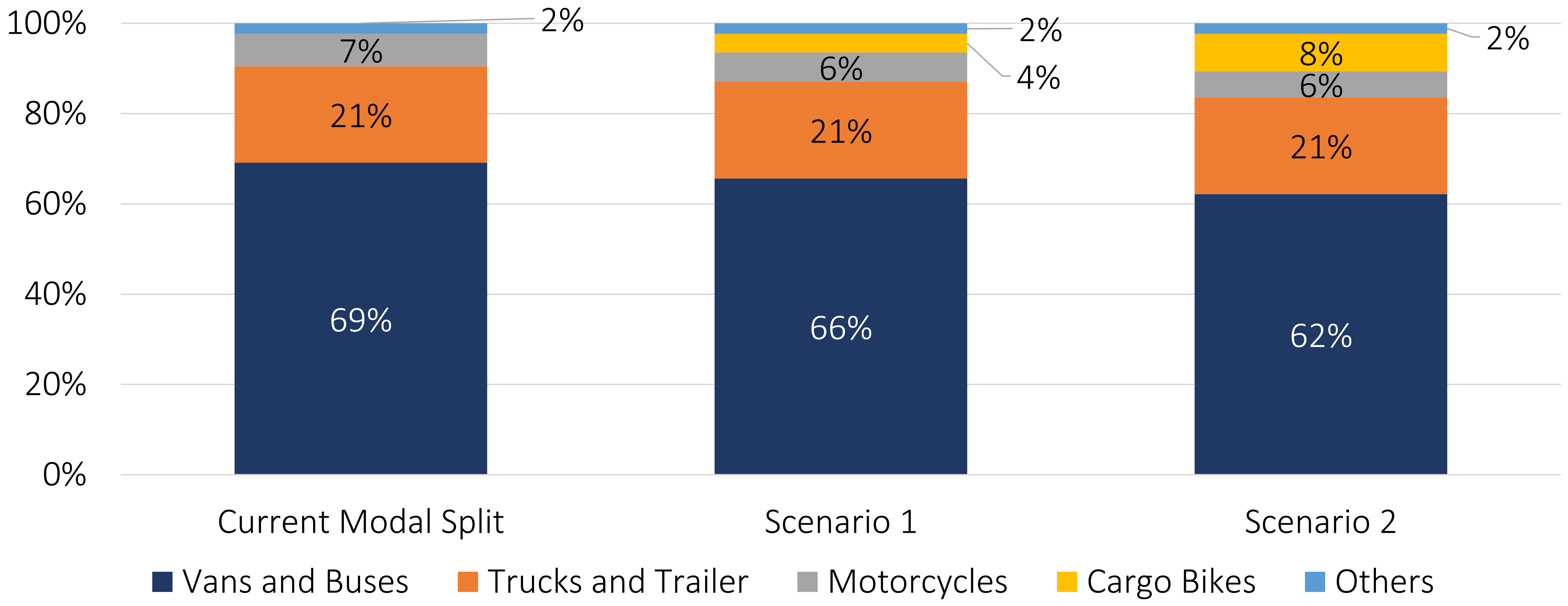
Range (full battery)

25 km

Payload capacity + utilization

1 person (80 kg) +
120 kg max. payload capacity
50% capacity utilization

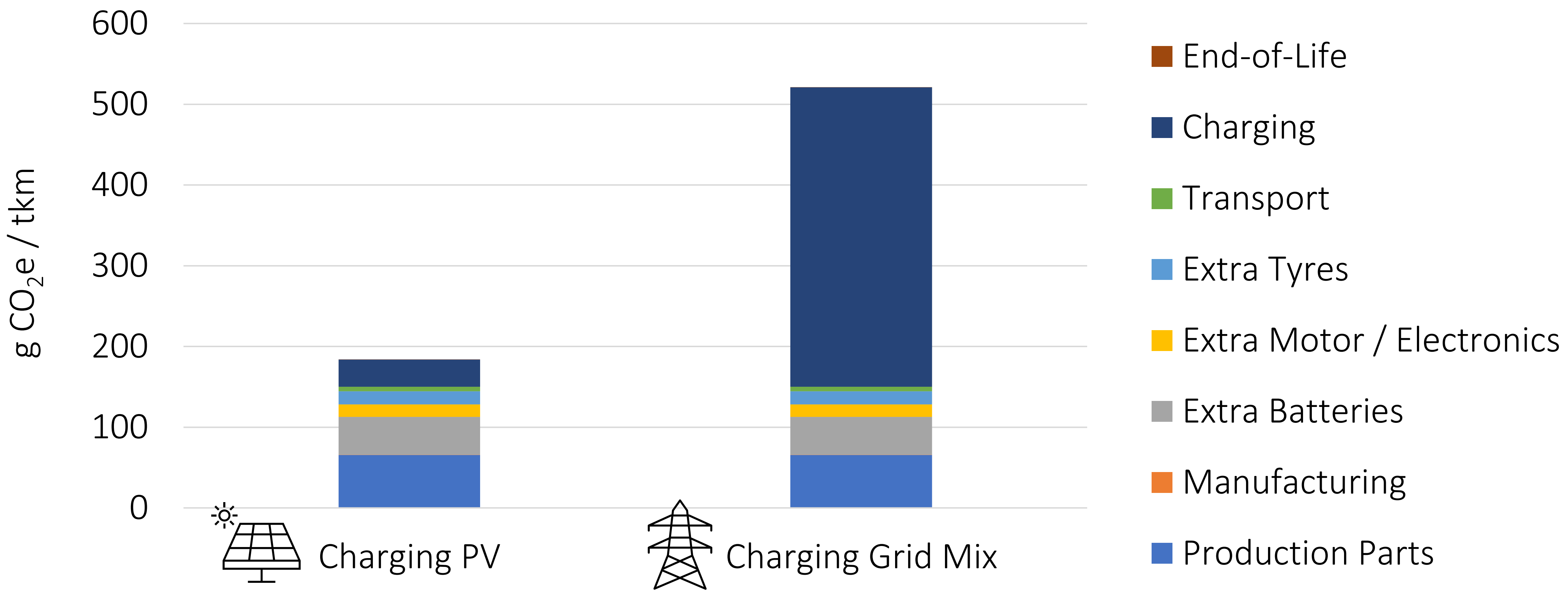
Methodology
Modal split



Modal split of freight transport in the Greater Accra region [5] and different scenarios for a modal shift after the implementation of e-cargo bikes.

Results

Life cycle GHG emissions per ton-kilometer

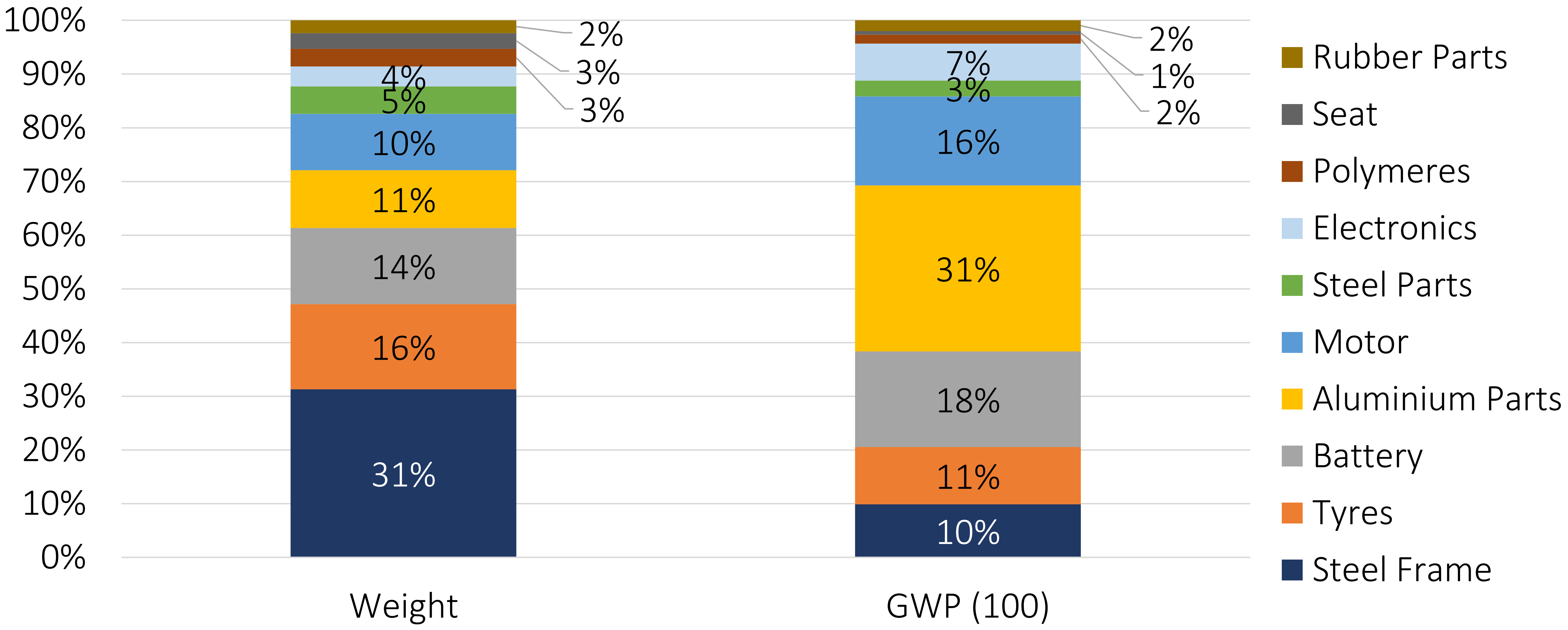


Life cycle GHG emissions per ton-kilometer of e-cargo bikes used in Ghana for different scenarios.

Sources: solar charging [9]; Charging Ghanian national grid [10]

Results

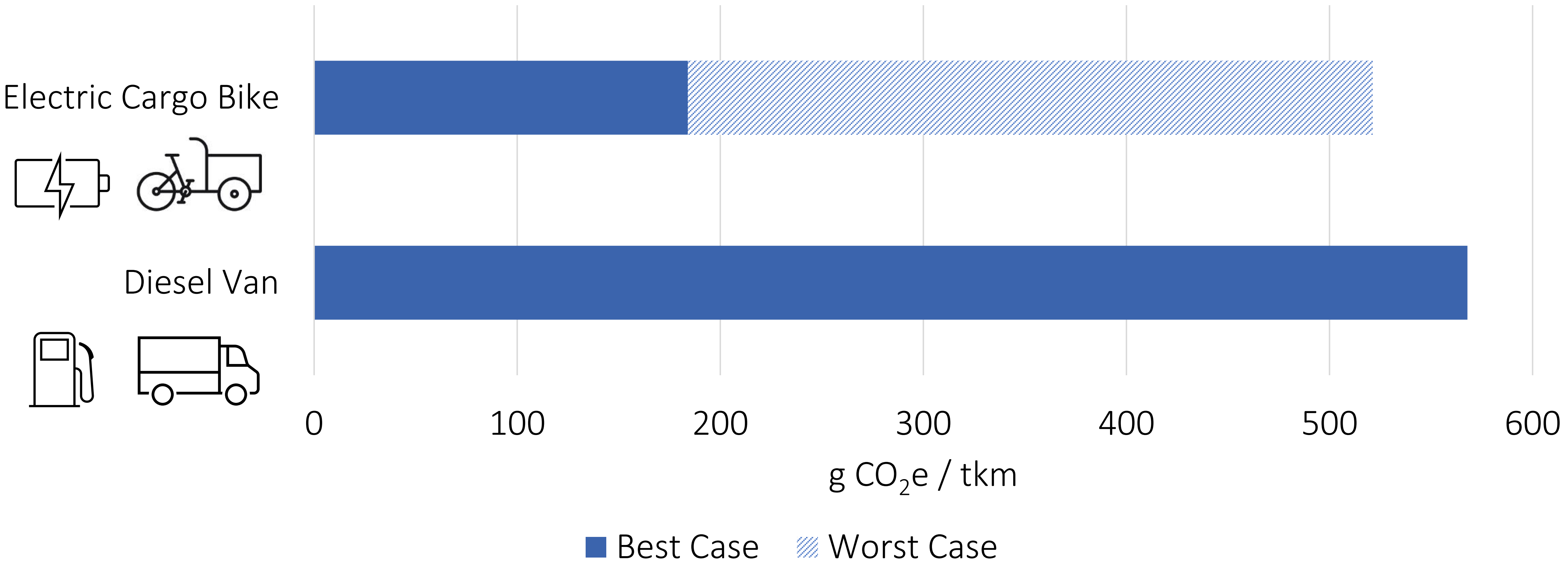
GHG emissions of materials for producing one e-cargo bike



Share of GHG emissions of different materials in the production of one e-cargo bike compared to their weight shares.

Results

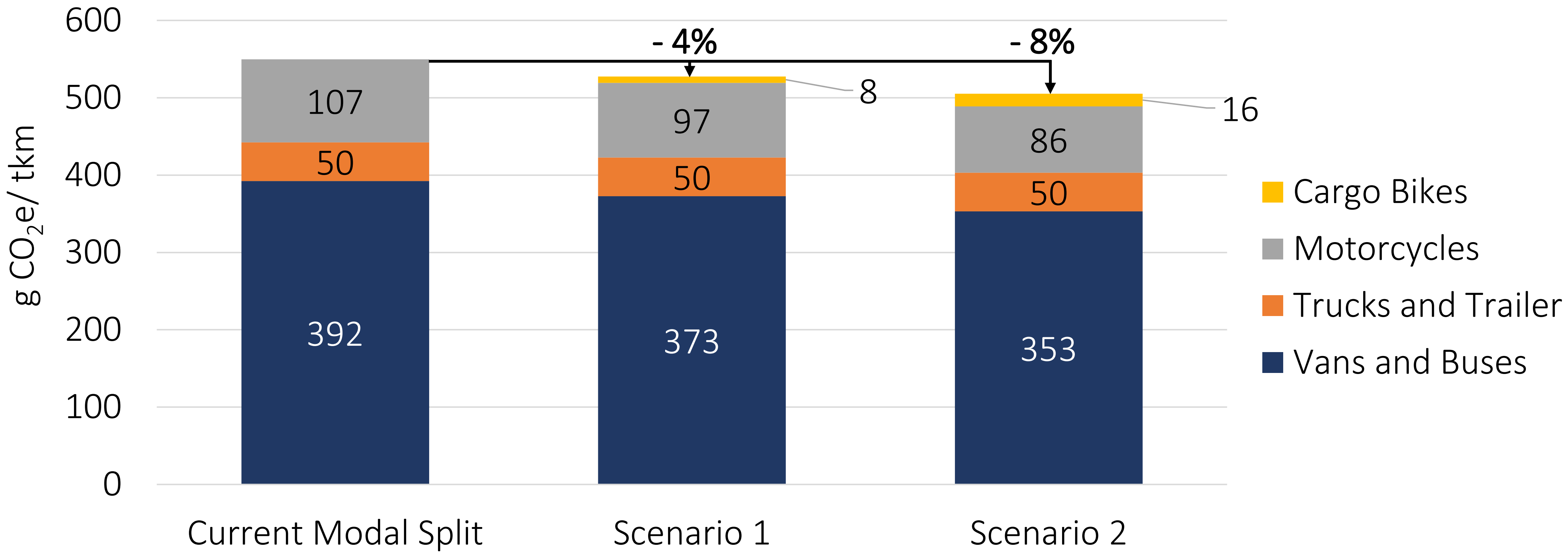
Comparison of GHG emissions for transportation in Ghana



Comparison of GHG emissions per ton-kilometer of a diesel van [11] and an electric cargo bike for transportation in Ghana.

Results

Comparison of GHG emissions for transportation in Ghana



Average GHG emissions of urban freight transport in the Greater Accra region per ton-kilometer for different modal splits based on emission factors [10] for motorcycles, trucks and vans as well as own calculations for the emissions of e-cargo bikes.

Discussion and Conclusion

1. Hotspot charging
   In case of intensive use battery charging is the main contributor to GHG emissions over the lifecycle
   → When charged with solar energy these emissions can be reduced by about 65% compared to charging with the Ghanian national grid

2. Hotspot lithium battery
   - Short lifetime compared to other components
   - Risk of dropouts with intense heat in Ghana
   - Energy intensive production

   → Use of more robust batteries such as solid-state batteries should be considered

3. Hotspot aluminum
   Produced in China with CO_2-intensive power mix and high energy demand for primary aluminum
   → Use of renewable energy for aluminum production and more secondary aluminum could be an alternative

E-cargo bikes can represent an environmentally friendly option for the urban freight transport system in Ghana with a potential reduction of 4-8% of GHG emissions per ton-kilometer if they can claim a significant share in the modal split and are charged with solar energy.

Discussion and Conclusion

Empirical data validation

- Due to the novelty of the product and use-case in Ghana mainly literature data and specifications from the manufacturer were used
- Empirical data validation will be conducted within the MoNaL project throughout this year at the Don Bosco Campus in Tema, Ghana

Further research

- NO_x and particulate matter emissions, as electromobility offers advantages especially regarding these local emissions
- Analysis of the cost reduction potential of e-cargo bikes
- Investigation of the effect on the Ghanaian urban transport system in more detail with empirical analysis of the current modal split in Ghanaian urban freight transport and the life cycle GHG emissions of alternative transport modes such as vans and trucks as well as scenarios for a potential share of e-cargo bikes in the modal split within the framework of user surveys or simulations

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Sources

[1] Somanje A, et al. Challenges and potential solutions for sustainable urban-rural linkages in a ghanaian context. Sustain., vol. 12, no. 2, pp. 1–19, 2020. Available from doi: 10.3390/su12020507.

[2] Ayetor GK, Mbonigaba I, Ampofo J, et al. Investigating the state of road vehicle emissions in Africa: A case study of Ghana and Rwanda. Transportation Research Interdisciplinary Perspectives. 2021;11:100409.

[3] International Organization for Standardization. Environmental management – life cycle assessment – principals and framework. International Standard ISO 14040. 2009.

[4] International Organization for Standardization. Environmental management – life cycle assessment – requirements and guidelines. International Standard ISO 14044. 2006.

[5] Foster P , Ramaswamy P , A rtaxo P , e t a l. Changes in Atmospheric Constituents and in Radiative Forcing. Climate Change 2007: The Physical Science Basis Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York: Cambridge University Press; 2007. p. 130–234.

[6] Sarbah A, Fokuh SK, Obeng E, et al. Managing city logistics in ghana. Trends, developmemts and its implications to city dwellers. International Journal of Economics, Commerce and Management. 2014;2.

[7] Melo S, Baptista P. Evaluating the impacts of using cargo cycles on urban logistics: integrating traffic, environmental and operational boundaries. Eur Transp Res Rev. 2017;9:30.

[8] Nürnberg M. Analysis of using cargo bikes in urban logistics on the example of Stargard. Transportation Research Procedia. 2019;39:360– 369.

[9] Sphera Solutions GmbH. GaBi Professional Datenbank 2021. Hintergrunddatenbank. 2021.

[10] Institute for Global Environmental Strategies. List of Grid Emission Factors version 10.10 [Internet]. 2021. Available from: https://pub.iges.or.jp/pub/iges-list-grid-emission-factors

[11] Umweltbundesamt - German Environmental Agency. Ökologische Bewertung von Verkehrsarten: Abschlussbericht. 2020; Available from: https://www.umweltbundesamt.de/sites/default/files/medien/479/publikat ionen/texte_156- 2020_oekologische_bewertung_von_verkehrsarten_0.pdf