planet A VENTURES

Life Cycle Assessment

Dance

Summary

Terminology and abbreviations

CED_f	Cumulative fossil energy demand
CO_2-eq.	Carbon dioxide equivalents
e-bike	electric bicycle
EOL	End of Life
Functional unit	Quantified performance of a product system for use as a reference unit
GHG	Greenhouse gas
LCA	Life cycle assessment
Sb-eq.	Antimony equivalents
WSI	Water Stress Index

About Dance

The transition towards more sustainable transportation systems mitigates climate change, reduces harmful air pollutants and increases the quality of life. Many European metropolitan areas are now seeking alternative modes of transport that offer more sustainable transportation options to their citizens. The start-up company Dance targets this market by offering a subscription model-based electric bike (e-bike) transportation service. Dance provides a personal e-bike to subscribing users.

About this study

This is a summary report of a detailed life cycle assessment (LCA) study evaluating the potential environmental impact of Dance. The LCA study was conducted in accordance with ISO 14040 and 14044 standards[1] for LCA. A consequential LCA approach was applied to evaluate the change in environmental indicators as a result of Dance's activity. The approach evaluates marginal changes within the overall economy as a consequence of a change in the market structure (e.g. entry of a new market participant such as Dance), production modalities, demands as well as political, consumer or any other decision affecting the former aspects (Ekvall et al. 2016). To account for marginal changes, marginal data is used wherever possible, e.g. marginal suppliers are identified and the change in their production output is considered (in contrast to using market averages).

System boundaries

The evaluation comprises the full life-cycle of Dance bicycles as well as other effects arising from Dance's activities (Figure 1). The LCA evaluates potential changes in environmental indicators. Hence, all processes and activities that increase or decrease their operation are considered. All green processes and activities depicted in Figure 1 will increase their output. All orange processes decrease their operation. These are processes related to the modal shift of Dance users and substitution of materials when used bikes are recycled. All energy requirements, waste streams, auxiliary materials etc. are considered (background processes). The operation of offices and all marketing activities are excluded from the assessment.

Aside from all processes operated by Dance and their suppliers, other transportation modes and market participants might also be affected by Dance. Most importantly, users of Dance will change their mobility behavior. Depending on the mobility behavior and availability of alternatives, Dance users will switch from other modes of travelling to using Dance's e-bike.

[1] EN 14040:2006 + AMD 1:2021 [EN ISO 14040:2006 + A1:2020] and ISO EN 14044:2016 + AMD 1:2018 + AMD 2: 2020 [ISO 14044:2006 + Amd 1:2018+ Amd 2:2020]

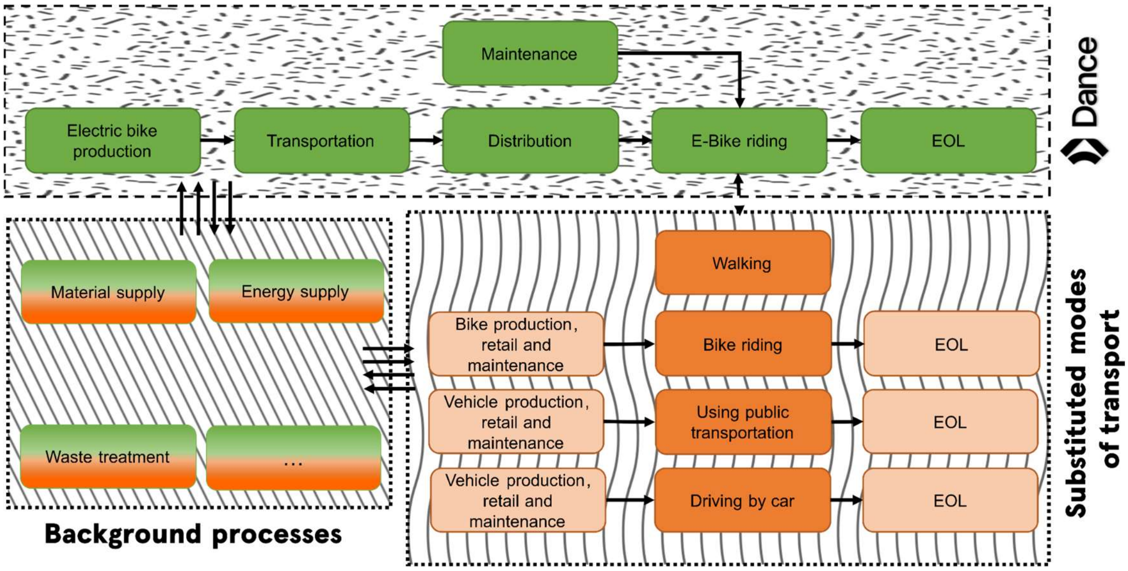

Figure 1 *Depiction of system boundaries. The assessed system comprises the life cycle of Dance bicycles and displaced modes of transport (modal shift). Two scenarios were evaluated: (i) a full displacement of other modes of transport (e.g. users do own/buy less cars) and (ii) a reduction in the respective mode of transport (e.g. users still buy/own cars, but use them less). Orange processes will cease to operate or will be less demanded. All processes considered in scenario (i) are depicted in light and dark orange. Scenario (ii) comprises processes in dark orange. Green processes will commence/increase operation due to Dance. Abbr.: EOL – End-of-life.*

Evaluated scenarios

Dance users can either use Dance to fully substitute certain modes of transportation or as an additional mode of transportation:

1. Dance results in a **full displacement of other transportation modes**: users will buy/own less cars or conventional bicycles. Dance bicycles substitute the full life-cycle of alternative transportation modes (i.e. production of bicycles and cars as well as fuel combustion of car usage).
2. Dance results in a **reduction in the use of other transportation modes**: Users will still buy/own cars and bicycles. They use Dance as an additional mode of transportation. Hence, Dance e-bikes substitute the use-phase of these alternative modes (i.e. fuel combustion of cars).

Public transportation is considered to remain unaffected: unless Dance reaches a very high market share of all transportation modes, it is unlikely that Dance will affect the public transportation system.

Context: Dance users can use the e-bikes to fully substitute other modes of transport (scenario ‘full displacement’). In such a case, users would, for example, not buy a car or an ordinary bicycle because they subscribed to Dance. Consequently, Dance e-bikes displace the production, use and EOL of these cars and bicycles. Alternatively, users could use Dance in addition to the other modes of transport (scenario ‘reduction in use’). In such a case, users would still buy and possess other (normal) bikes and cars. They would simply use them less frequently. In such a case, Dance e-bikes only substitutes the use phase (e.g. fuel combustion of car usage, the use phase of the bike is considered to have no impact).

Functional unit and assessed indicators

The functional unit of this study is **one person moving one kilometer (1 p*km)** with a Dance e-bike. In total, **four LCA indicators** are evaluated:

1. climate change (IPCC 2013 Intergovernmental Panel on Climate Change (IPCC) 2014),
2. abiotic resource depletion (CML 2001 v. 4.7 2016 CML - Department of Industrial Ecology 2016),
3. cumulative fossil energy demand (CED_f), and
4. water demand (WSI Pfister et al. 2009).

The first indicator is the most commonly used indicator to evaluate the potential impact on the climate (even though the global warming potential (GWP) itself does not inform about the *impact* on the climate). The other indicators reflect the use of resources.

Context: The functional unit chosen is 1 person travelling 1 km. This functional unit was chosen because it is the most suitable unit to compare different modes of transport. It makes different modes of transport comparable: e.g., it allows to compare the GHG emissions of traveling 1 km using a Dance e-bike with driving a car. In contrast, other functional units, such as the overall impact over the full life-cycle of a bike, would not allow such a comparison.

Life cycle stages and modal shifts

The life-cycle of a Dance e-bike comprises the following stages (all green processes depicted in the frame labelled ‘Dance’ in Figure 1). All processes are modelled with the Ecoinvent 3.7 database (Wernet et al. 2016).

Life cycle of Dance e-bikes

The life cycle of Dance e-bikes comprises:

- **Bicycle production.** Dance’s electric bicycles are manufactured and assembled in China. The bikes are made of an aluminum frame, an electric motor, a Li-ion battery and other standard bicycle components (tires, brakes, pedals, chain, crankset, etc.). The frame, motor and battery weigh 3.900, 2.480 and 2.300 g, respectively. The average life-time of a bike is 11.000 km. Modern batteries last for the whole lifetime of a bike. All other parts and corresponding weights and material compositions were taken from (Wernet et al. 2016; Leuenberger and Frischknecht 2010).

- **Bicycle transport.** Bicycles are shipped from China to Europe. In addition, it is assumed that e-bikes are transported by truck for 500 km.

- **Bicycle distribution.** Bikes are distributed using electric vans. So far, no data was available. This stage was therefore excluded from the assessment.

- **Bicycle use.** The use phase comprises charging of the bike. The bike requires in average 5.277 MJ per 100 km (Ji et al. 2014; Machedon-Pisu and Borza 2020; Gebhard et al. 2016; Wachotsch et al. 2014; Frischknecht et al. 2016; Leuenberger and Frischknecht 2010).

- **Maintenance.** On a regular basis, bikes are maintained. The maintenance includes the manufacturing of spare parts and the disposal of bike parts. Metals are recycled. Plastic and rubber is incinerated in municipal solid waste treatment plants. Data was taken from (Wernet et al. 2016).
- **End-of-life (EOL).** Electric bicycles are assumed to be recycled. All metal parts are recycled. Plastics are incinerated in municipal solid waste plants. Batteries are recycled using hydrometallurgical processes (Brückner et al. 2020; Hischier et al. 2007). Metals, e.g. aluminum, steel, copper and lithium are recycled and reduce the demand for virgin metals.

Substitution of other means of transport: modal shifts

The use of Dance e-bikes most likely displaces other means of transport. These **modal shifts** are modelled as depicted in Figure 1. The modal shifts reported in literature and used within this study refer to the displaced share of travelling distance using a certain mode of transport.

Two comprehensive literature studies were used to derive an average modal shift (Figure 2). Users were asked to keep track of their mobility behavior (travelled distances by different modes of transport). **The modal shift depicted in Figure 2 presents the share of modes of transport that were displaced by e-bike use.**

Context: The shares shown in Figure 2 refer to the former modes of transport that were displaced by the e-bike usage. E.g. an average user using an e-bike for 100 km per year used a car to cover 52 km (52 %) of these 100 km before using the e-bike. The share does not give any indication of the overall modes of transportations chosen by the users and the overall distances covered by them. These values only show the **modal shift**, that is, the modes of transport users used before using the e-bike to travel those distances they are now travelling with an e-bike.

The two literature studies used report surveys among e-bike user in urban areas: Munich, Frankfurt, Bremen-Oldenburg and Brunswick-Hannover (216 participants Kämper et al. 2016), and Berlin and its periphery (629 participants Czowalla 2016). The gender and age distributions of interviewed participants are depicted in Figure 3.

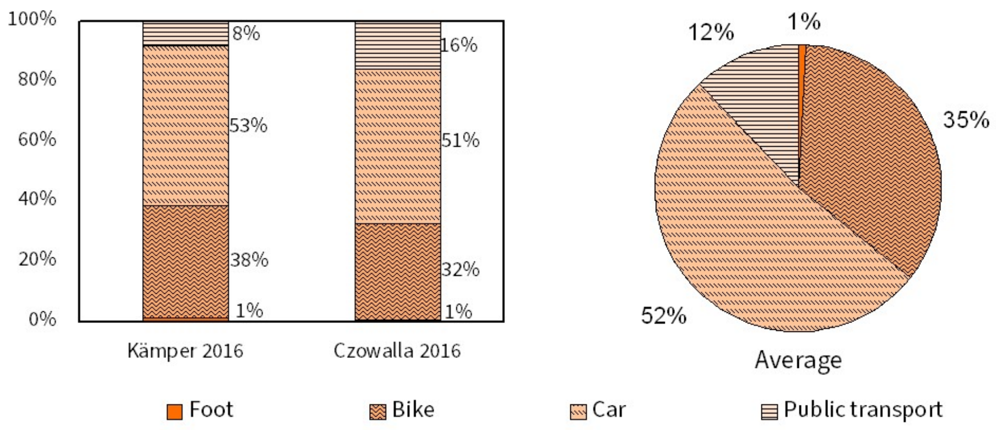

Figure 2 *Modal shifts of e-bike users reported in two comprehensive literature studies (Czowalla 2016), Kämper et al. 2016). These studies (left) were used to derive an average displacement of modes of transport (right).*

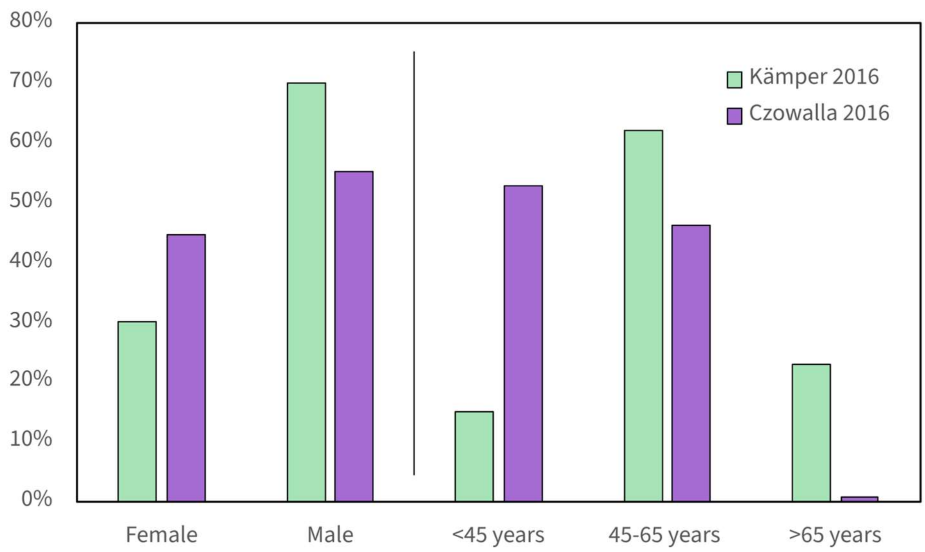

Figure 3 *Gender and age distributions of participants of surveys among e-bike users (Czowalla 2016; Kämper et al. 2016).*

The geographical context and age distribution of the literature studies indicate that they might be suitable to estimate the potential behavior of Dance users. Caveat: the design Dance's e-bikes targets a young and urban target group, whereas the studies focused on classical pedelecs and e-bikes. Hence, Dance users might be younger and fewer of them might possess cars. Still, these studies present the most reliable and detailed evaluation of user behavior in urban areas that was found. They were therefore considered reasonably suitable for this assessment.

For all displaced transportation modes, energy consumption, fuel provision and maintenance are accounted for. This comprises:

- Scenario 'full displacement: The production, use and EOL of cars; production and EOL of bicycles (use of normal bicycles is assumed to have no impact).
- Scenario 'reduction in use: The use phase of cars (fuel provision and combustion). The use phases of other modes of transport are not relevant in this scenario.

Conducted sensitivity analysis

In addition to the base case using average data (data described above), a **sensitivity analysis** was conducted:

- **Parameter variation.** Minimum and maximum cases were calculated based on a variation of important input parameters (Table 1). The minimum and maximum cases reflect the **minimum and maximum impact of Dance** based on a parameter variation of important parameters. The minimum and maximum values used in the parameter variation were derived from a literature review and data provided by Dance. Reviewed literature: (Ji et al. 2014; Machedon-Pisu and Borza 2020; Gebhard et al. 2016; Wachotsch et al. 2014; Frischknecht et al. 2016; Leuenberger and Frischknecht 2010; Oesterreich 2018; Bosch eBike Systems - Robert Bosch GmbH 2020; Hodgins 2021)

  Table 1 *Parameter variation of important parameters.*

	unit	**Average**	**Minimum**	**Maximum**
Life-time of the e-bike	km	11 000	12 000	9 000
Number of batteries over life-time	unit	1	1	3
Weight of batteries	g	2 300	2 000	5 700
Electricity demand	MJ/ 100 km	5.3	1.7	14.4

- **Linear optimization.** A linear optimization was conducted to determine the minimum share of car usage displaced required to achieve **a net improvement in all impact categories or a decrease in GHG emissions**.

  Context: The mobility behavior of citizens depends on many factors, such as a different socio-economic status, accessibility to other modes of transport (e.g. cars), perception of different modes of transport, societal acceptance of certain modes of transport, political decisions, personal preferences, infrastructure, weather, costs, etc. All these aspects might differ in different locations, among different user types. They also change over time. It is therefore uncertain whether or not the reported modal shifts reflect the modal shifts of Dance users. To account for this uncertainty, the linear optimization was conducted to determine a minimum modal shift that is needed to result in a positive impact in all indicators or just climate change. Such a modal shift expresses the minimum share of the considered modes of transport that needs to be substituted by e-bike users in order to result in a positive impact. A comparison with the modal shifts reported in literature allows to get a better understanding of the likelihood of a net positive impact of Dance.

- **Alternative electricity mix.** According to the consequential approach marginal data is applied as a change in demand affects a marginal supplier. The **marginal electricity supply** in many (but not all) European countries mainly comprises renewable energy sources. Often, studies apply average data in order. To allow a comparison to such studies, results are also presented if the **average electricity mix** was used for calculation purposes. An increase in demand triggers an increase in electricity supply from marginal suppliers, not average suppliers. Using average electricity mixes does not give an indication on the change in environmental indicators Dance might trigger.

  Context: The assessment follows a consequential LCA approach. According to the approach's logic, marginal data is used. For example, a market entry of Dance, assuming a significant market penetration, will increase the demand for electricity. Such an increase in demand will result in marginal electricity suppliers to supply the corresponding amount of electricity to the market. The environmental impact, e.g. the GHG intensity, of the marginal electricity supply differs from the average because other technologies supply the marginal increase in production. The marginal supplier depends on many factors, such as prices, infrastructure, regulation, customers' choices etc. In many European countries, the marginal electricity supply mainly comprises electricity from renewable sources, whereas the average electricity mix still comprises a much higher share of fossil fuels.

  Applying marginal data provides insights in the potential changes in environmental impacts of Dance, whereas applying average Data tells more about the average impact of using a

Dance e-bike (for example in comparison to another mode of transportation). The study was conducted to gain insights into the former aspect. To allow a better comparison with other studies applying the latter approach, the results on the average electricity mix are also presented. All other data sets are still marginal datasets.

Dance's environmental impact

In the following sections the net change in evaluated indicators is presented. First, general results are presented. Subsequently the results of the sensitivity analysis are discussed.

General results

The most important contributor to the environmental impact of the life-cycle of Dance e-bikes is the production and provision of material (Figure 4). The production dominates all assessed impact categories. Surprisingly, the use phase only contributes a comparably small share to the overall impact (see sensitivity analysis below for further evaluations on the effect of changing the applied electricity mix).

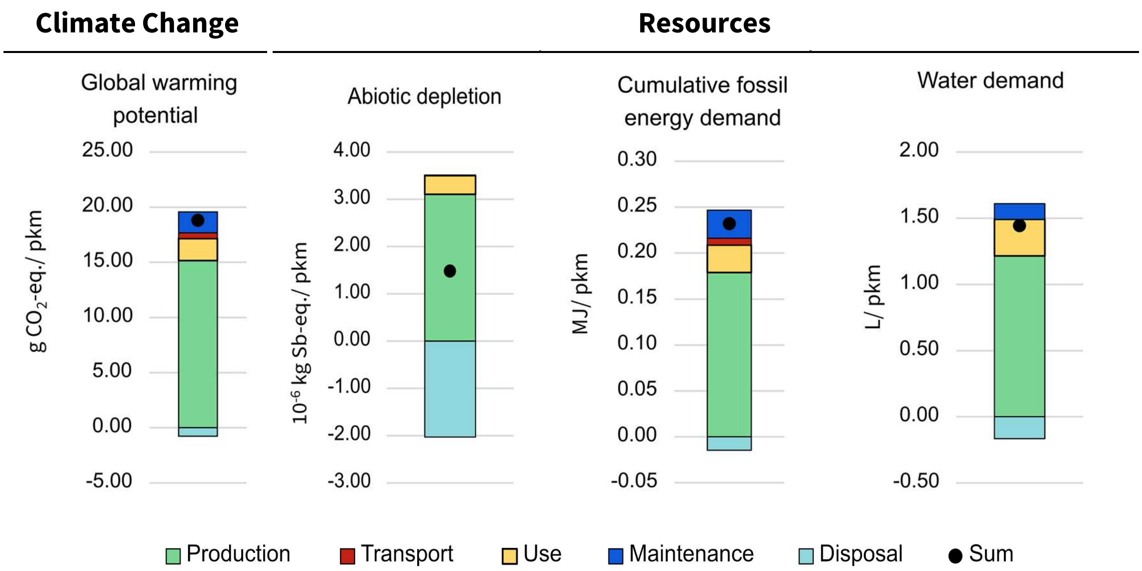

Figure 4 *Detailed depiction of change in evaluated indicators of the life cycle of Dance e-bikes (green life-cycle stages depicted in Figure 1).* ***Context:*** *All indicator scores are presented according to the defined functional unit, i.e. 1 person riding 1 km by e-bike. Therefore, all depicted life-cycle stages except for the use phase depend on the life-time usage of the bike. For example, the global warming potential (GHG emissions) of the production was derived from the absolute GHG emissions for the e-bike production divided by life-time range of an e-bike (11 000 km, see Table 1). In contrast, the use phase comprises the energy demand per km ridden. Therefore, the use phase is independent of the life-time range of the e-bike. The negative impact of the disposal arises from the displacement of virgin materials occurring at the EOL (recycling). The depicted black dot is the sum of all life-cycle stages.*

The sum depicted in Figure 4 can also be interpreted as the additional impact that Dance potentially causes, if the users do not displace any car use at all and use Dance only instead of walking or non-electric bicycle riding (still buying/owning these bikes).

If users displace the modes of transport and the corresponding shares as reported in literature, Dance results in an overall net reduction in assessed indicator scores (Figure 5). Therefore, it can be concluded that **Dance is likely to result in a net improvement in environmental impacts** if users follow the modal shift as reported in literature. In all evaluated impact categories except water demand, Dance results in a net reduction of environmental impacts, even if users still own cars or bicycles and Dane results only change of their mobility behavior (scenario ‘reduction in use).

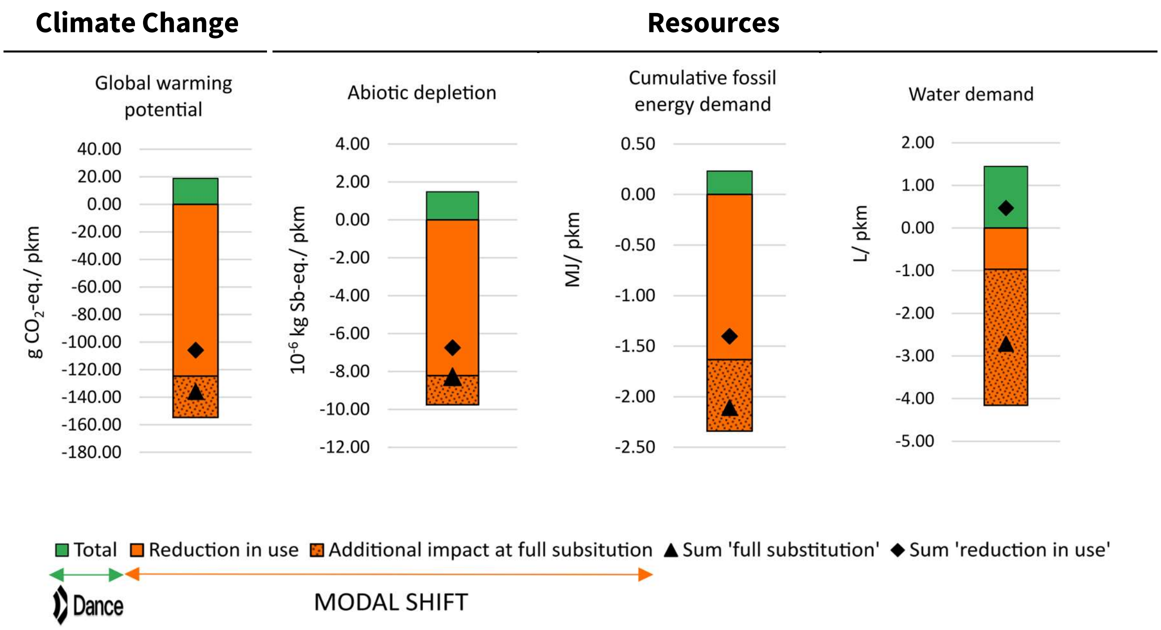

Figure 5 *Overall change in evaluated indicators including modal shift of users (all elements depicted in Figure 1).* ***Context:*** *Again, all indicator scores are presented according to the defined functional unit, i.e. 1 person riding 1 km by e-bike. The orange bars represent the impact of the displaced modes of transport according to the modal shift. The blank orange bars are those impacts avoided in the ‘reduction in use’ scenario, i.e. the use phase of cars. All other use phases are assumed to have no impact (e.g. walking or non-electric bicycles) or are assumed not to change (i.e. public transport). The stacked patterned bars are additional reductions in impact due to the substitution of the production and EOL of the displaced modes of transport, i.e. car and bicycle production and EOL. The depicted sums reflect the change in impact that is triggered by Dance if users follow the modal shift. The values can be multiplied with the total distance covered by Dance users (assuming that all users in sum behave according to the modal shift) to obtain the absolute impact Dance generates.*

Sensitivity analysis

Several important aspects were evaluated in a sensitivity analysis:

- **Parameter variation.** Minimum and maximum cases were defined by varying important parameters (Table 1). The evaluation shows that overall results are not very sensitive with regards to these parameters in all impact categories except water demand (Table 2). In all impact categories but the indicator water demand, overall net changes in environmental indicators differ by less than 10% from the base case in case of the minimum and maximum cases.

Table 2 *Overview on change in environmental indicators per km. Minimum and maximum values in parentheses (see Table 1 for differences of the average, minimum and maximum cases).*

	Climate change	**Resources**		
	Global warming potential	**Abiotic depletion**	**Cumulative fossil energy demand**	**Water demand**
	g CO_2-eq./ km	10^{-6} kg Sb-eq./ km	MJ/ km	L/ km
Full substitution	-135.89	-8.04	-2.11	-2.71
	(-141.12 to -123.50)	(-8.60 to -6.37)	(-2.13 to -1.92)	(-2.71 to -1.72)
Reduction in use	-105.83	-6.50	-1.40	0.48
	(-108.59 to -95.90)	(-6.89 to -5.00)	(-1.40 to -1.30)	(0.55 to 1.39)

- **Linear optimization.** A linear optimization was conducted to evaluate the share of modes of transport that need to be replaced at a minimum in order to result in a net reduction in either all indicators or climate change only (global warming potential). The results reveal that **Dance only needs to substitute a small share of car driving in order to result in a net benefit for the climate** (Table 3). The share is well below what is reported in literature studies on the modal shifts (Figure 2). If all impact categories are to be reduced, the share of car rides to be replaced is higher than what is reported in literature on modal shifts.

Table 3 *Minimum percentage of other modes of transport to be displaced by Dance in order to achieve a net reduction in all indicators or in the indicator global warming potential (GWP). Values in parentheses present minimum and maximum values derived from applying the minimum and maximum cases of the parameter variation.*

Scenario	**Displaced mode of transport**	**All indicators**	**Only climate change (GWP)**
Full displacement	Bicycle rides	89%	97%
		(88 - 0%)	(98 - 94%)
	Cars	11%	3%
		(12 - 32%)	(2 - 6%)
Reduction in use	Cars	78%	8%
		(82% - 20%[a])	(7 - 12%)

[a] There is no net decrease in water demand in this case. The linear optimization was executed without setting the water demand as a boundary condition in this case.

Context: The values reported in Table 3 present break-even points of the substitution of car usage (in case of the 'reduction in use' scenario), and bike and car use (in the 'full displacement' scenario). The sum of all distances covered with Dance e-bikes needs to displace at least the stated percentage of cars in order to result in an overall net positive impact. The overall impact of Dance is positive as long as the average of all distances covered by Dance e-bikes displaces the reported shares, even if individual customers behave differently. The average of all distances matters.

The minimum shares of car rides to be displaced by Dance in almost all cases is well below the share of car rides displaced in the modal shifts reported in literature. It can be concurred that it is likely that Dance results in a net positive impact as considerably less car rides need to be displaced than what was reported in literature.

- **Alternative electricity mix.** Often, average electricity mixes are applied in studies. Applying average electricity mixes does conceptually not provide any insights into potential changes in environmental impacts that might arise from the introduction of a novel technology or service, e.g. Dance e-bike subscription model. In order to give an indication on the influence of the applied electricity mix, the average electricity mix was applied, too (see section 'Conducted sensitivity analysis' for further details). The results show that the electricity mix is of minor importance when it comes to net changes in GHG emissions (Figure 6). The modal shift of users is much more important than the electricity used to operate Dance e-bikes.

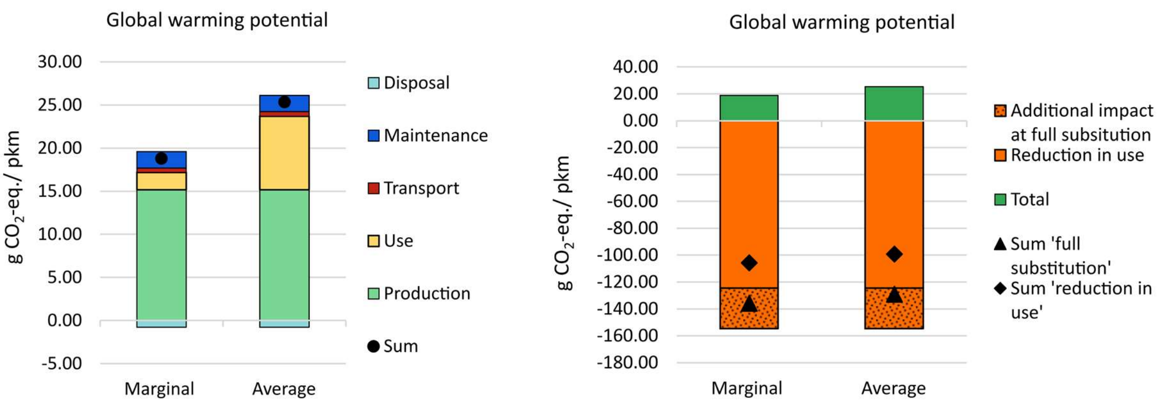

Figure 6 *Influence of the electricity mix: marginal vs. average.*

Conclusion

The evaluation of Dance e-bikes reveals that Dance is likely to result in a **net reduction in the evaluated environmental impact categories**. **Dance is likely to reduce GHG emissions and the demand for resources**. Of all processes within the supply chain of Dance, the production of e-bikes is a key driver of the environmental impacts. Most importantly, resources (e.g. metals) used for bike parts have a high influence. The electricity demand is of minor importance regarding the overall impact. The increase in electricity demand that is triggered by Dance users is likely to come from electricity from renewable sources as in many European countries additional demand of electricity is supplied by renewable energy.

The most important factor lies outside of Dance`s direct influence: user behavior. **The modal shift of Dance users is crucial to reach a positive impact** (regarding the evaluated indicators). Dance must displace a certain share of car rides in order to generate a positive impact. How easily this can be achieved depends on the targeted customers. To maximize the environmental benefits, it is advisable to specifically target user groups that use cars or to promote the substitution of car usage among Dance users.

References

Bosch eBike Systems - Robert Bosch GmbH (Ed.) (2020): The e-Bike rechargeable battery guide. Reutlingen.

Brückner, Lisa; Frank, Julia; Elwert, Tobias (2020): Industrial Recycling of Lithium-Ion Batteries—A Critical Review of Metallurgical Process Routes. In *Metals* 10 (8), p. 1107. DOI: 10.3390/met10081107.

CML - Department of Industrial Ecology (Ed.) (2016): CML-IA Characterisation Factors. 05 September 2016. Leiden.

Czowalla, Lucas (2016): EBikePendeln - Nutzung- und Akzeptanzkriterien von Elektrofahrrädern im beruflichen Pendelverkehr. Abschlussbericht der wissenschaftlichen Begleitforschung. Edited by Institut für Transportation Design (ITD) - Braunschweig University of Art. Braunschweig.

Ekvall, Tomas; Azapagic, Adisa; Finnveden, Göran; Rydberg, Tomas; Weidema, Bo P.; Zamagni, Alessandra (2016): Attributional and consequential LCA in the ILCD handbook. In *Int J Life Cycle Assess* 21 (3), pp. 293–296. DOI: 10.1007/s11367-015-1026-0.

Frischknecht, Rolf; Messmer, A.; Stolz, Phillipe; Tuchschmid, M. (2016): mobitool - Grundlagenbericht. Hintergrund, Methodik & Emissionsfaktoren. Edited by treeze Ltd. Bern.

Gebhard, Lukas; Golab, Lukasz; Keshav, S.; Meer, Hermann de (2016): Range Prediction for Electric Bicycles. In : e-Energy '16: Proceedings of the Seventh International Conference on Future Energy Systems. e-Energy '16: Seventh International Conference on Future Energy Systems. Waterloo, Canada, June 21-24. New York, NY, USA: Association for Computing Machinery (e-Energy ’16). Available online at https://doi.org/10.1145/2934328.2934349.

Hischier, Roland; Classen, M.; Lehmann, M.; Scharnhorst, W. (2007): Life Cycle Inventories of Electric and Electronic Equipment - Production, Use & Disposal. Edited by Swiss Centre for Life Cycle Inventories, Empa/Technology & Society Lab. Dübendorf.

Hodgins, Dan (2021): How Much Do Electric Bikes Weigh? Available online at http://ebiketroop.com/how-much-do-electric-bikes-weigh/, checked on 4/13/2021.

Intergovernmental Panel on Climate Change (IPCC) (Ed.) (2014): Climate Change 2013 - The Physical Science Basis. Cambridge: Cambridge University Press.

Ji, Shuguang; Cherry, Christopher R.; Han, Lee D.; Jordan, David A. (2014): Electric bike sharing. Simulation of user demand and system availability. In *Sustainable Development of Energy, Water and Environment Systems* 85, pp. 250–257. DOI: 10.1016/j.jclepro.2013.09.024.

Kämper, C.; Helms, H.; Jöhrens, J. (2016): Modal Shifting Effects and Climate Impacts through Electric Bicycle Use in Germany. In *Journal of Earth Sciences and Geotechnical Engineering* 6 (4), pp. 331–345.

Leuenberger, Marianne; Frischknecht, Rolf (2010): Life Cycle Assessment of Two Wheel Vehicles. Implemented in ecoinvent data v2.2 (2010). Edited by ESU-services GmbH. Uster.

Machedon-Pisu, Mihai; Borza, Paul Nicolae (2020): Are Personal Electric Vehicles Sustainable? A Hybrid E-Bike Case Study. In *Sustainability* 12 (1), p. 32. DOI: 10.3390/su12010032.

Oesterreich, Julia (2018): Wie hoch sind die Betriebskosten beim e-Bike? Edited by eBike News. Available online at https://ebike-news.de/wie-hoch-sind-die-betriebskosten-beim-e-bike/172376/, updated on 1/13/2018, checked on 4/13/2021.

Pfister, Stephan; Koehler, Annette; Hellweg, Stefanie (2009): Assessing the Environmental Impacts of Freshwater Consumption in LCA. In *Environ Sci Technol* 43 (11), pp. 4098–4104. DOI: 10.1021/es802423e.

ISO 14044:2006 + Amd 1:2018+ Amd 2:2020: Umweltmanagement – Ökobilanz – Anforderungen und Anleitungen.

EN ISO 14040:2006 + A1:2020: Umweltmanagement – Ökobilanz – Grundsätze und Rahmenbedingungen.

Wachotsch, Ulrike; Kolodziej, Andrea; Specht, Bernhard; Kohlmeyer, Regina; Petrikowski, Falk (2014): E-Rad macht mobil. Potenziale von Pedelecs und deren Umweltwirkung. Edited by Umweltbundesamt. Dessau-Roßlau.

Wernet, Gregor; Bauer, Christian; Steubing, Bernhard; Reinhard, Jürgen; Moreno-Ruiz, Emilia; Weidema, Bo (2016): The ecoinvent database version 3 (part I). Overview and methodology. In *Int J Life Cycle Ass* 21 (9), pp. 1218–1230. DOI: 10.1007/s11367-016-1087-8.

planet A
VENTURES

www.planet-a.com