



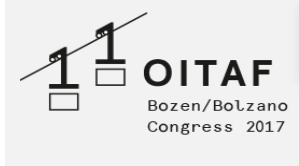
ECOLOGICAL FOOTPRINT OF A ROPEWAY INSTALLATION IN URBAN AREAS

Klaus Erharter



Ecological footprint of a ropeway installation in urban areas

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Index

1. Introduction
2. Lifecycle Assessment (LCA) - Methodology
3. System definition
4. Data sources and calculation model
5. System comparison
6. Conclusion





1. Introduction

1.1 Sustainable Development (SD)

Definitions of Sustainability

Sustainable Development (SD)

Meeting the needs of the present generation
without compromising the ability of future generations
to meet their own needs.



-- Brundtland Commission, 1987 --

Sustainability

The possibility that human and other forms of life on earth
will flourish forever.

-- John Ehrenfeld, Professor Emeritus. MIT --

Sustainable Development (SD)

Enough - for all -- forever.

-- African Delegate to Johannesburg (Rio+10) --



1. Introduction

1.1 Sustainable Development



Earth Summit 2002 – Johannesburg declaration

„...accordingly, we assume a collective responsibility to advance and strengthen the interdependent and mutually reinforcing pillars of sustainable development

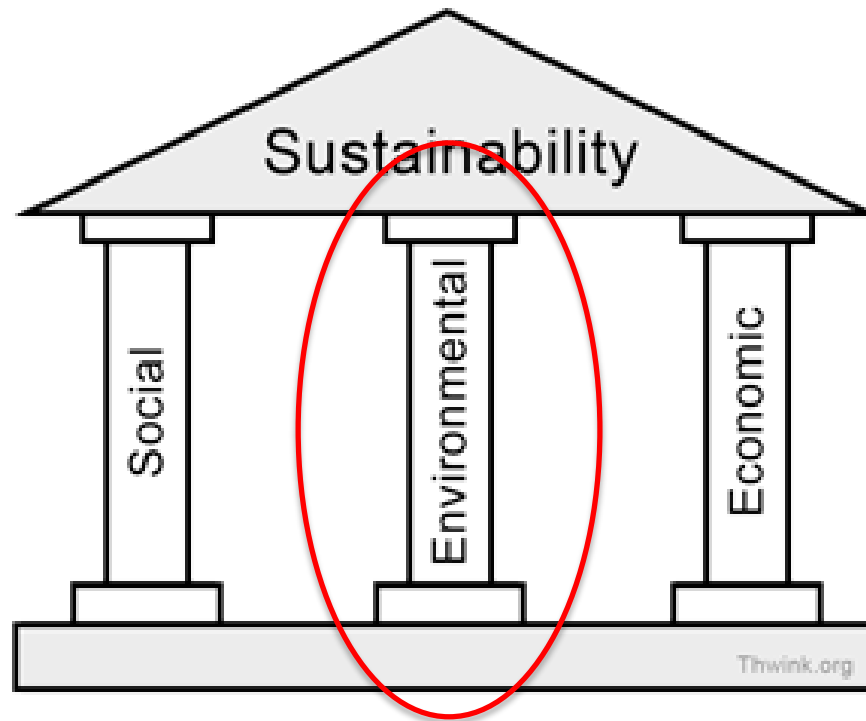
- Economic development,
- Social development and
- Environmental protection

at the local, national and global levels.“



1. Introduction

1.2 Three pillars model

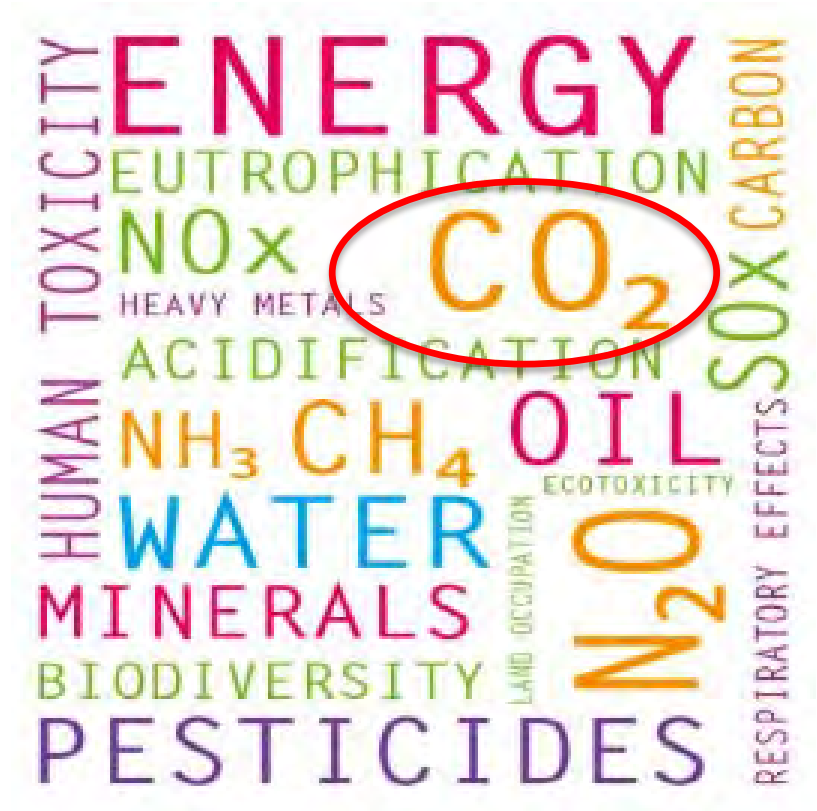




1. Introduction

1.3 Lifecycle Assessment (LCA)

- Life Cycle Assessment (LCA) according to ISO14044 & ISO14040
- Environmental Product Declaration (EPD) according to ISO14025
- European Lifecycle Database (ELCD)
- Product Environment Footprint (PEF)
- Energy Efficient Buildings (EeBGuide)
- ...



Source: Wikipedia



2. Lifecycle Assessment (LCA) - Methodology

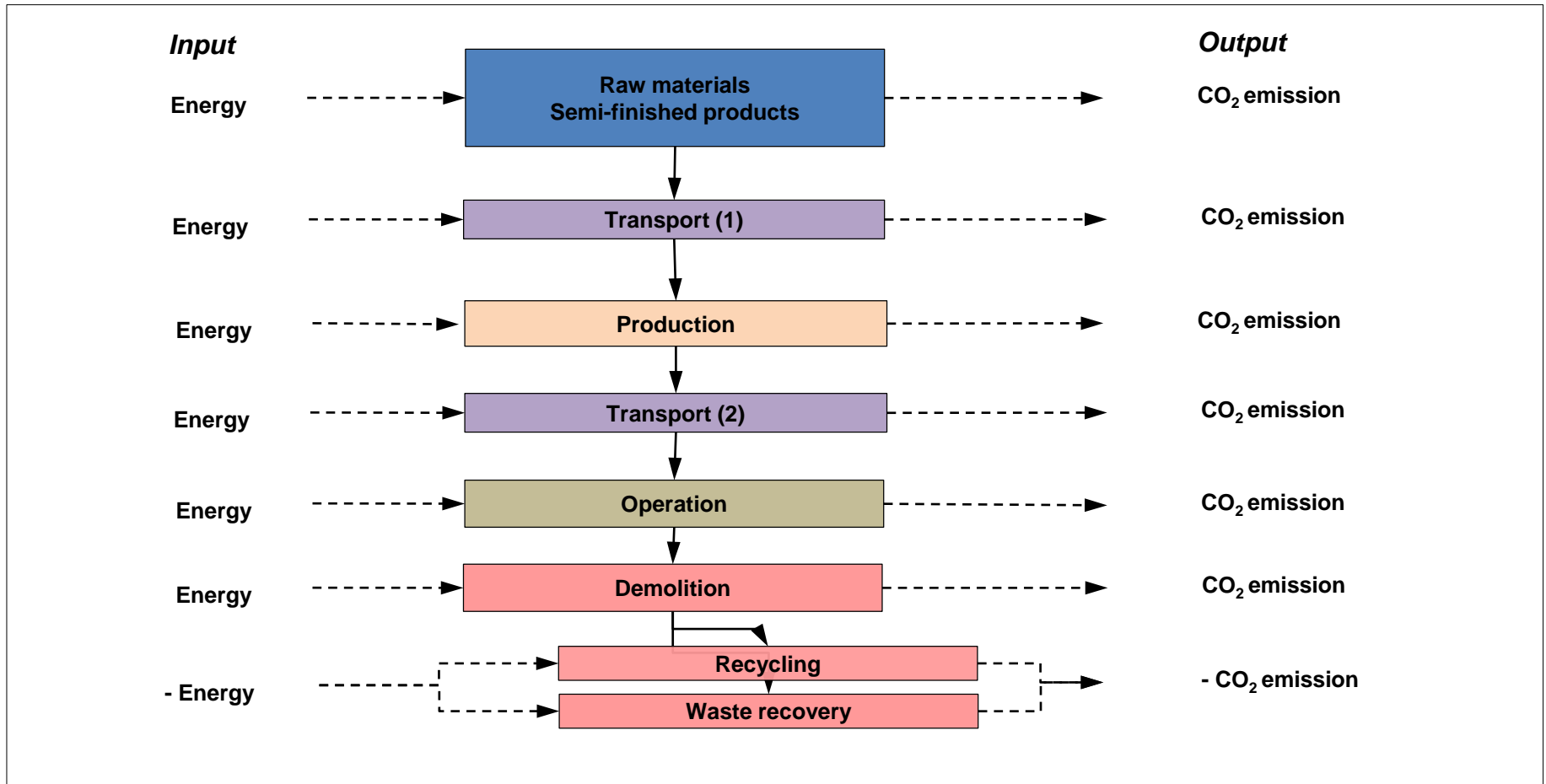
2.1 Ecological footprint – a lifecycle analysis





2. Lifecycle Assessment (LCA) - Methodology

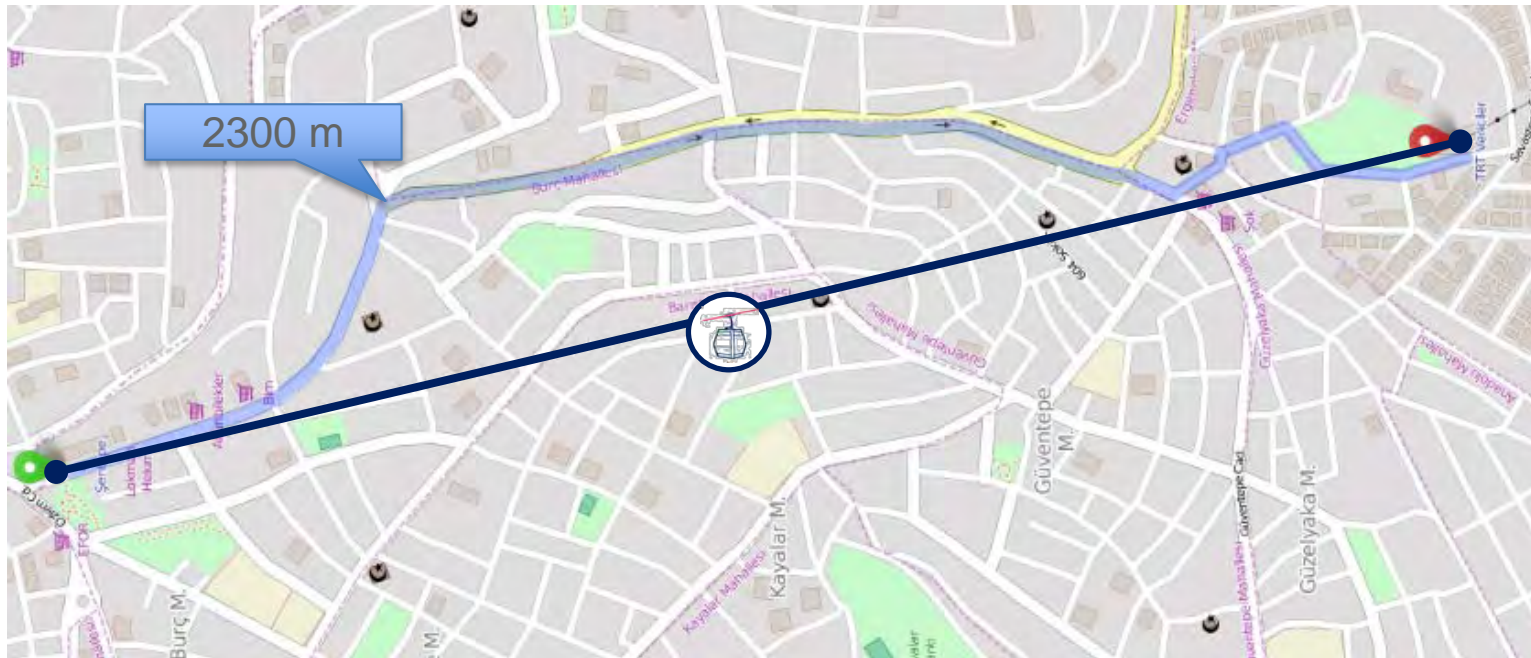
2.2 LCA – Set of unit processes within the product system












3. System definition

3.1 System description Ropeway GD10 Yenimahalle, Ankara (Turkey)



3. System definition

Utilization of the system:
2.500.000 people per year
per direction [pppd]

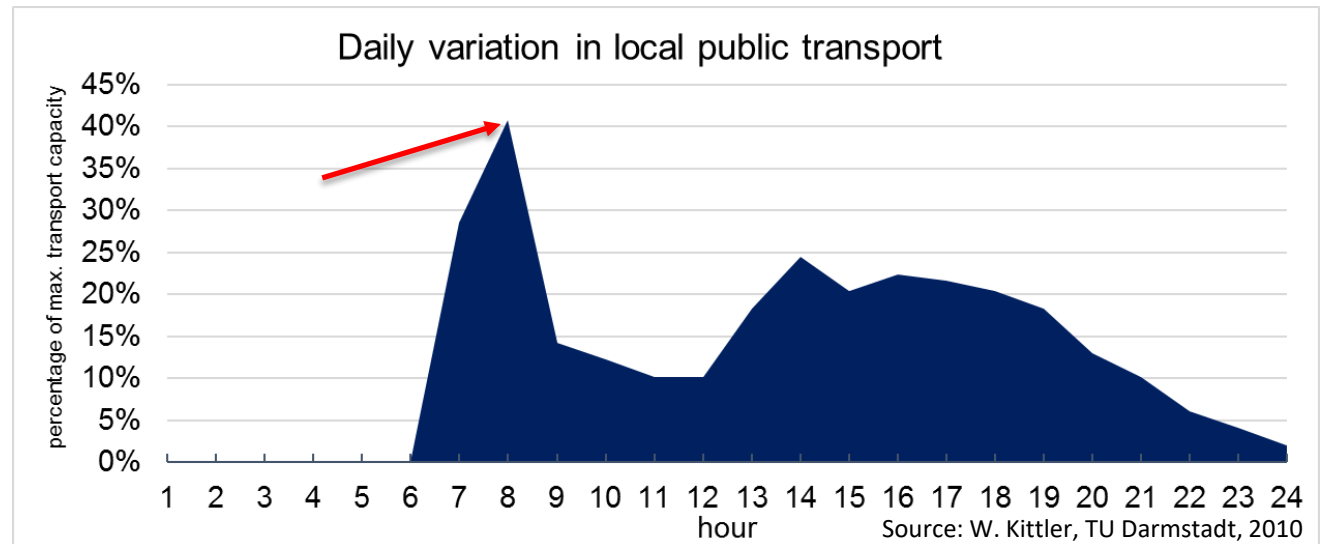
-  35 years
-  1881,7 m
-  75 m
-  2400 pphpd
-  315 – 425 kW
-  88 p
-  9 p



Boarding area



Drive unit





4. Data sources and calculation model

4.1 Data sources



1 Mineralische Baustoffe

2 Dämmstoffe

3 Holz

4 Metalle

→ 4.1 Stahl und Eisen

→ 4.1.04 Stahlbleche

Feuerverzinktes Stahlblech

Stahl Feiblech (0,3-3,0mm)

Stahl Feiblech (20µm verzinkt)

→ Stahl warmgewalzte Bleche (2-20mm)

5 Beschichtungen

6 Kunststoffe

7 Komponenten von Fenstern und Vorhangfassaden

8 Gebäudetechnik

9 Sonstige



4. Data sources and calculation model

4.1 Data sources

Indikator ↕	Einheit ↕	Herstellung A1-A3	Beseitigung C4	Recyclingpotential D
<u>Potenzial für den abiotischen Abbau nicht fossiler Ressourcen (ADPE)</u>	<u>kg Sb-Äqv.</u>	1.476E-7	3.295E-10	-1.407E-8
<u>Potenzial für den abiotischen Abbau fossiler Brennstoffe (ADPF)</u>	<u>MJ</u>	24.27	0.01158	-12.95
<u>Versauerungspotenzial von Boden und Wasser (AP)</u>	<u>kg SO2-Äqv.</u>	0.007999	0.000005383	-0.005402
<u>Bildungspotenzial für troposphärisches Ozon (POCP)</u>	<u>kg Ethen-Äqv.</u>	0.001154	5.099E-7	-0.0008009
<u>Eutrophierungspotenzial (EP)</u>	<u>kg Phosphat-Äqv.</u>	0.0007008	7.384E-7	-0.0004529
<u>Abbaupotenzial der stratosphärischen Ozonschicht (ODP)</u>	<u>kg R11-Äqv.</u>	1.57E-11	1.418E-14	1.543E-11
<u>Globales Erwärmungspotenzial (GWP)</u>	<u>kg CO2-Äqv.</u>	2.139	0.0008872	-1.389



4. Data sources and calculation model

4.2 Calculation model

a) Production - Demolition - Recycling of raw materials (steel sheet 2-20 mm)

Weight data from bill of material

Global Warming Potential:

Stufe	Material	Kurzbezeichnung	(Gesamtgewicht) kg	Materialart	Wert	Einheit	INPUT
1	84010396	TDS_RETUR_GD10 SOGN MARTIN-LA SIALA (CH)	127.735,08		95.167,72		PERT
2	84010588	TDS_R_GRO_GD10 SOGN MARTIN-LA SIALA (CH)	20.298,32		13.841,00		PERT
3	41009765-04	UMLENKGRUPPE-WEG 5M+1M 4900D 1000kN	16.254,64	kg	9.803,00		PERT
3	50102758-02	HI-SPANNWEHR.US-5+1M-650KN H	4.043,69	kg	4.038,00		PERT
2	84010589	TDS_R_STR_GD10 SOGN MARTIN-LA SIALA (CH)	60.466,35		47.423,20		PERT
3	50220757-03	TRAGSTRUKTUR GD8 NO M. >4000	31.945,75	kg	25.513,00		PERT
3	50104267	Module vormontiert	7.422,79	kg	5.811,00		PERT
3	50100105	HOHE STRUKTUR LPA L=15.5m	8.247,14	kg	6.915,00		PERT
0	10000062	HEA-TRAEGER S355J0 HEA300	1.324,62	kg		1 kg	PERT
0	10000065	HEA-TRAEGER S355J0 HEA400	4.350,72	kg		1 kg	PERT
0	10000332	STAHLBLECH S275J0 15MM	10,81	kg		1 kg	PERT
0	10000345	STAHLBLECH S355J2 20MM	31,95	kg		1 kg	PERT
0	10000361	STAHLBLECH S355J2 30MM	622,95	kg		1 kg	PERT
0	10000373	STAHLBLECH S355J2 35MM	50,43	kg		1 kg	PERT
0	10001401	STAHLBLECH S355J2 15MM	1.229,52	kg		1 kg	PERT
0	10100024	FEUERVERZINKUNG STANDARD	324,00	kg		1 kg	PERT
1	15101935	KLEBESCHILD CE - RICHTLINE 20	0,00	kg		1 kg	PERT
1	20000110	SK-SCHRAUBE M30X120 8.8ISO4017	7,41	kg		1 kg	PERT
1	20002072	SK-MUTTER HV M30 10 EN 14399-4	19,92	kg		1 kg	PERT
1	20002075	BEILAGSCHEIBE 30 EN 14399-6	8,70	kg		1 kg	PERT
1	20005017	SK-MUTTER M30 8 ISO4032	3,94	kg		1 kg	PERT

$$GWP = \text{material weight} \cdot \text{Factor } GWP_{\text{steel sheet}}$$

Example

$$GWP = 42,76 \text{ kg steel sheet} \cdot 0,7509 \frac{\text{kgCO}_2 \text{ equivalent}}{\text{kg}} = 32,11 \text{ kg CO}_2 \text{ equivalent}$$



4. Data sources and calculation model

4.2 Calculation model – production of components

b) Production of ropeway components

Denomination	Value	Unit	Data source
Production hours Machining	1704	h	Production planning LEITNER ropeways
Production hours Welding	3220	h	
Production hours Assembling	1738	h	
Production hours Others	1057	h	
El. power Machining	70	kW	
El. power Welding	50	kW	
El. power Assembling	5	kW	
El. power Others	40	kW	

GWP calculated based on energy mix of production plants

(Leitner plants ~100% renewable energy sources)

4. Data sources and calculation model

4.2 Calculation model – concrete works

c) Erection of the ropeway

Stufe	Material	Kurzbezeichnung	Einheit	Gewicht kg/X	[Gesamtgewicht] kg	INPUT	Produkt Herstellung A1-A3	Produkt Beseitigung C4	Produkt Recyclingpotential D	Produkt Bilanz A1-D	Ergebnis-einheit	
0	DRIVE-Station Beton + Bewehrung					PERT	7.562,44	14,55	-	899,48	6.677,51	kWh
1	770081566	Schalplan - Beton Massen	68,75	m³	1	PERT	1.487,33	14,55	-	899,48	602,40	kWh
2		Beton C25/30	59,15	m³	1	PERT	1.266,80	12,52	-	773,88	505,44	kWh
2		Beton C30/37	9,6	m³	1	PERT	220,53	2,03	-	125,60	96,97	kWh
1	77008158	Bewehrung Stationsfundament-Unterteil 1	8271	kg	1	PERT	4.321,60	-	-	4.321,60	kWh	
2		Bewehrungsstahl D12	38	kg	1	PERT	19,86	-	-	19,86	kWh	
2		Bewehrungsstahl D14	802	kg	1	PERT	419,05	-	-	419,05	kWh	
2		Bewehrungsstahl D16	2868	kg	1	PERT	1.498,53	-	-	1.498,53	kWh	
2		Bewehrungsstahl D20	3211	kg	1	PERT	1.677,75	-	-	1.677,75	kWh	
2		Bewehrungsstahl D28	1352	kg	1	PERT	706,42	-	-	706,42	kWh	
1	77008159	Bewehrung Stationsfundament-Unterteil 2	1746	kg	1	PERT	912,29	-	-	912,29	kWh	
2		Bewehrungsstahl D12	141	kg	1	PERT	73,67	-	-	73,67	kWh	
2		Bewehrungsstahl D14	0	kg	1	PERT	-	-	-	-	kWh	
2		Bewehrungsstahl D16	331	kg	1	PERT	172,95	-	-	172,95	kWh	
2		Bewehrungsstahl D20	78	kg	1	PERT	40,76	-	-	40,76	kWh	
2		Bewehrungsstahl D28	1196	kg	1	PERT	624,91	-	-	624,91	kWh	
1	77008160	Bewehrung Stationsfundament-Oberteil	1610	kg	1	PERT	841,23	-	-	841,23	kWh	
2		Bewehrungsstahl D12	195	kg	1	PERT	101,89	-	-	101,89	kWh	
2		Bewehrungsstahl D14	362	kg	1	PERT	189,15	-	-	189,15	kWh	
2		Bewehrungsstahl D16	111	kg	1	PERT	58,00	-	-	58,00	kWh	
2		Bewehrungsstahl D20	333	kg	1	PERT	173,99	-	-	173,99	kWh	
2		Bewehrungsstahl D28	609	kg	1	PERT	318,20	-	-	318,20	kWh	

Calculation of GWP using the same methodology as shown in 4.2 a)



4. Data sources and calculation model

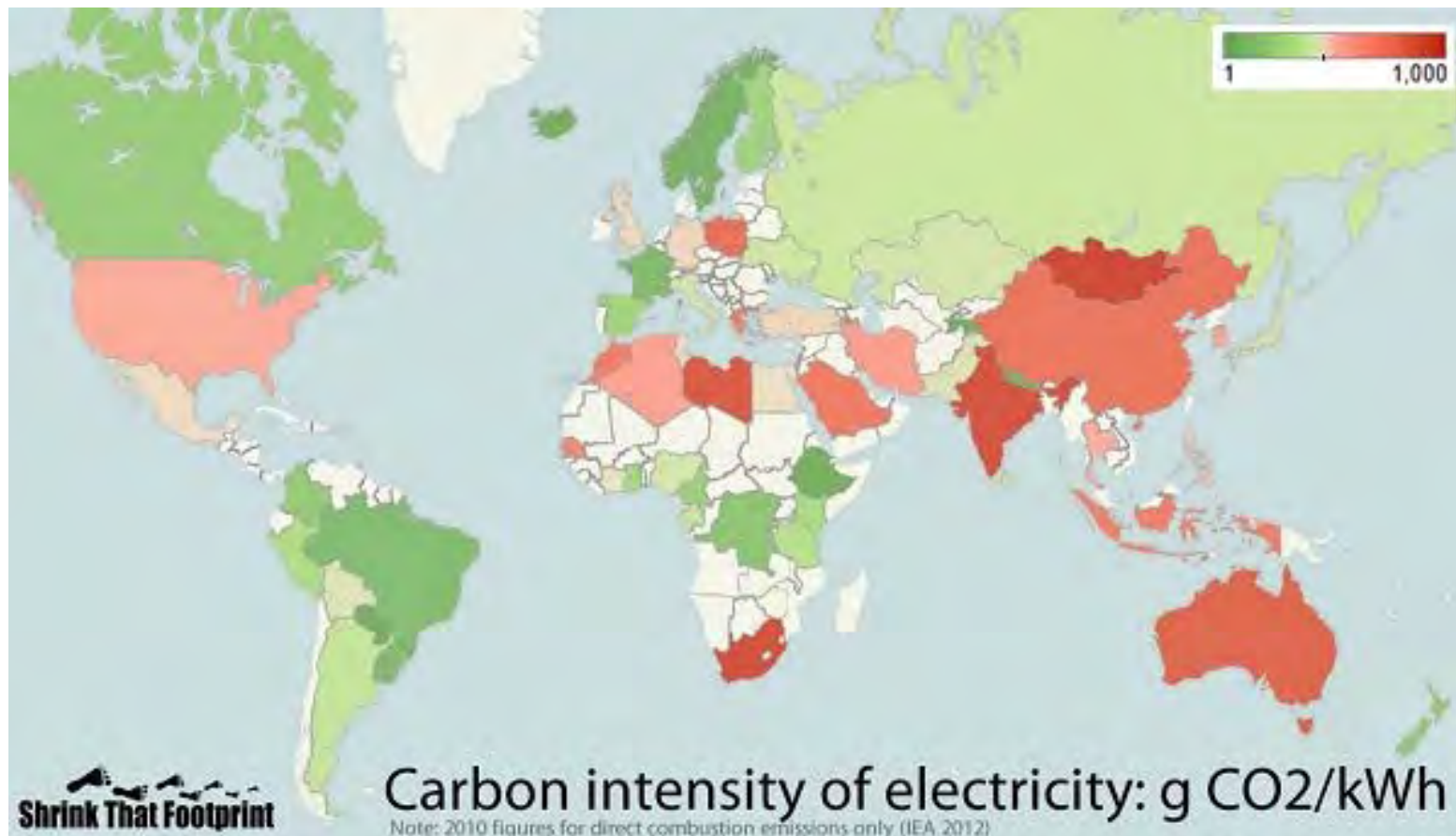
4.2 Calculation model – operation of the ropeway

Time of day		Monday - Friday operation	Diurnal variation characteristics	Diurnal variation daily share	Nr. of passengers in both directions	Utilization factor	Energy consumption [kWh]
from	to						
0	1	0	0%	0,00%	-	0%	0,0
1	2	0	0%	0,00%	-	0%	0,0
2	3	0	0%	0,00%	-	0%	0,0
3	4	0	0%	0,00%	-	0%	0,0
4	5	0	0%	0,00%	-	0%	0,0
5	6	0	0%	0,00%	-	0%	0,0
6	7	1	70%	0,50%	1.370	20%	346,4
7	8	1	100%	13,70%	1.957	41%	359,8
8	9	1	35%	4,73%	665	14%	330,7
9	10	1	30%	4,11%	587	12%	328,5
10	11	1	25%	3,42%	489	10%	326,2
11	12	1	25%	3,42%	489	10%	326,2
12	13	1	45%	6,16%	881	18%	335,2
13	14	1	60%	8,22%	1.174	24%	341,9
14	15	1	50%	6,85%	978	20%	337,4
15	16	1	55%	7,53%	1.076	22%	339,7
16	17	1	53%	7,26%	1.037	22%	338,8
17	18	1	50%	6,85%	978	20%	337,4
18	19	1	45%	6,16%	881	18%	335,2
19	20	1	32%	4,38%	626	13%	329,4
20	21	1	25%	3,42%	489	10%	326,2
21	22	1	15%	2,05%	294	6%	321,7
22	23	1	10%	1,37%	196	4%	319,5
23	24	1	5%	0,68%	98	2%	317,2
24	Sum		730%	100%	14286	17%	5997



4. Data sources and calculation model

4.2 Calculation model – energy mix

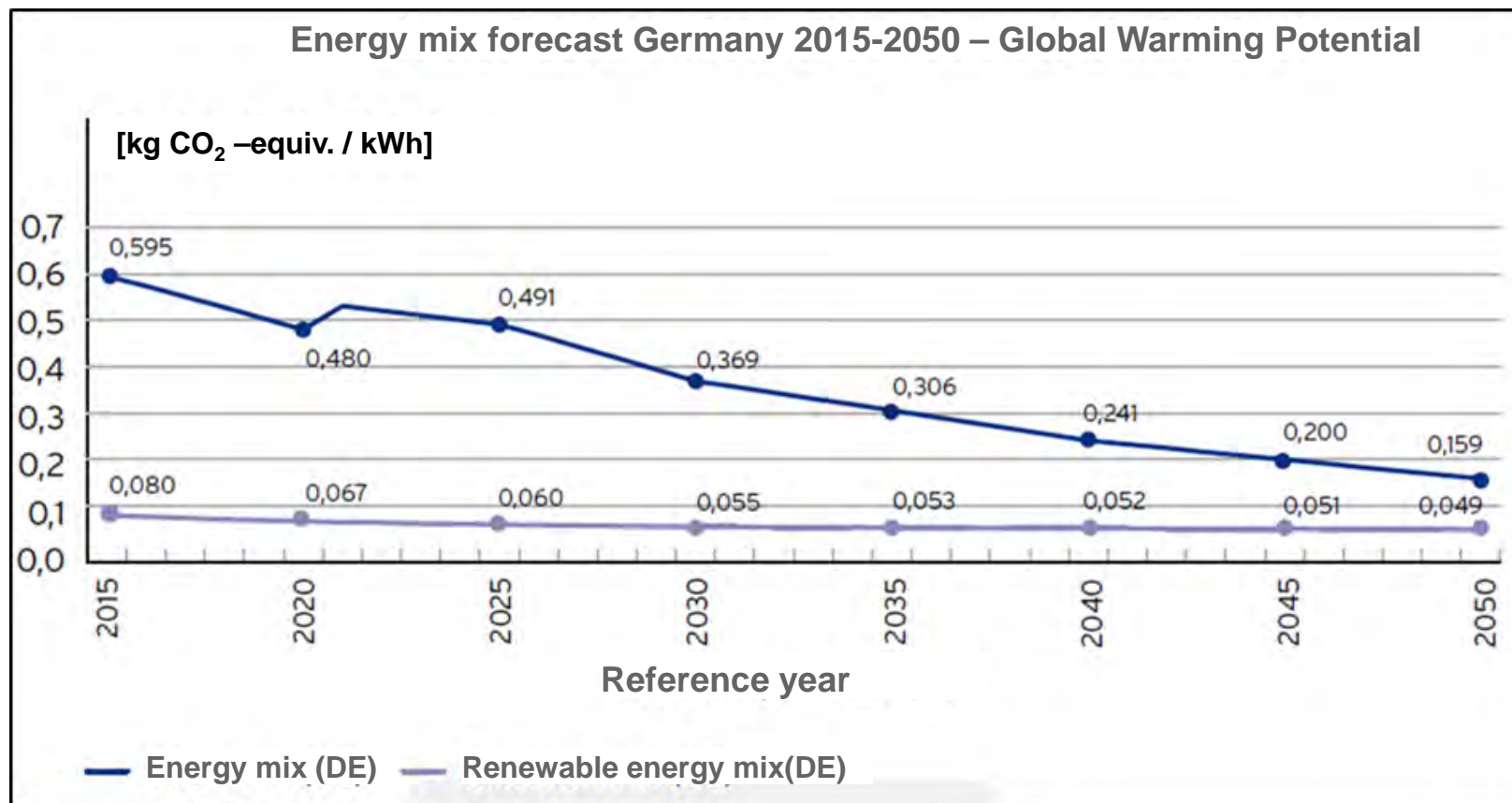


Source: greenbiz.it



4. Data sources and calculation model

4.2 Calculation model – energy mix forecast Germany



Source: BM für Verkehr und digitale Infrastruktur, 2016



4. Data sources and calculation model

4.2 Calculation model – operation of the ropeway

d) Operation of the ropeway

Calculation Global warming potential (year 2015)

$$GWP = \text{energy consumption p. y.} \cdot \text{Factor GWP (energy mix DE 2015)}$$

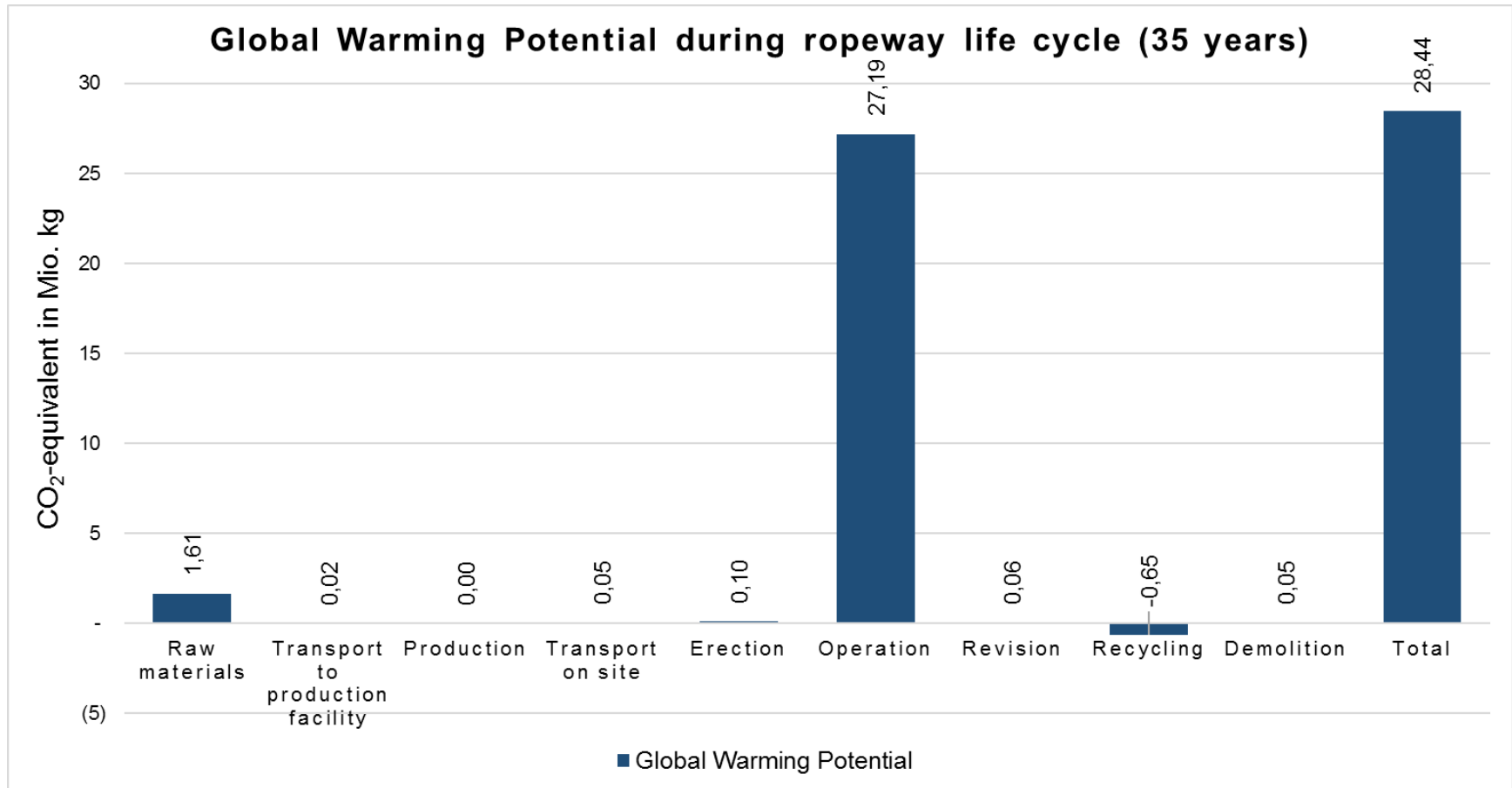
Example

$$GWP = 2.100.467 \frac{kWh}{y} \cdot 0,549 \frac{kgCO_2 \text{ equivalent}}{kg} = 1,153 \frac{Mio. kgCO_2 \text{ equivalent}}{y}$$



4. Data sources and calculation model

4.3 Results

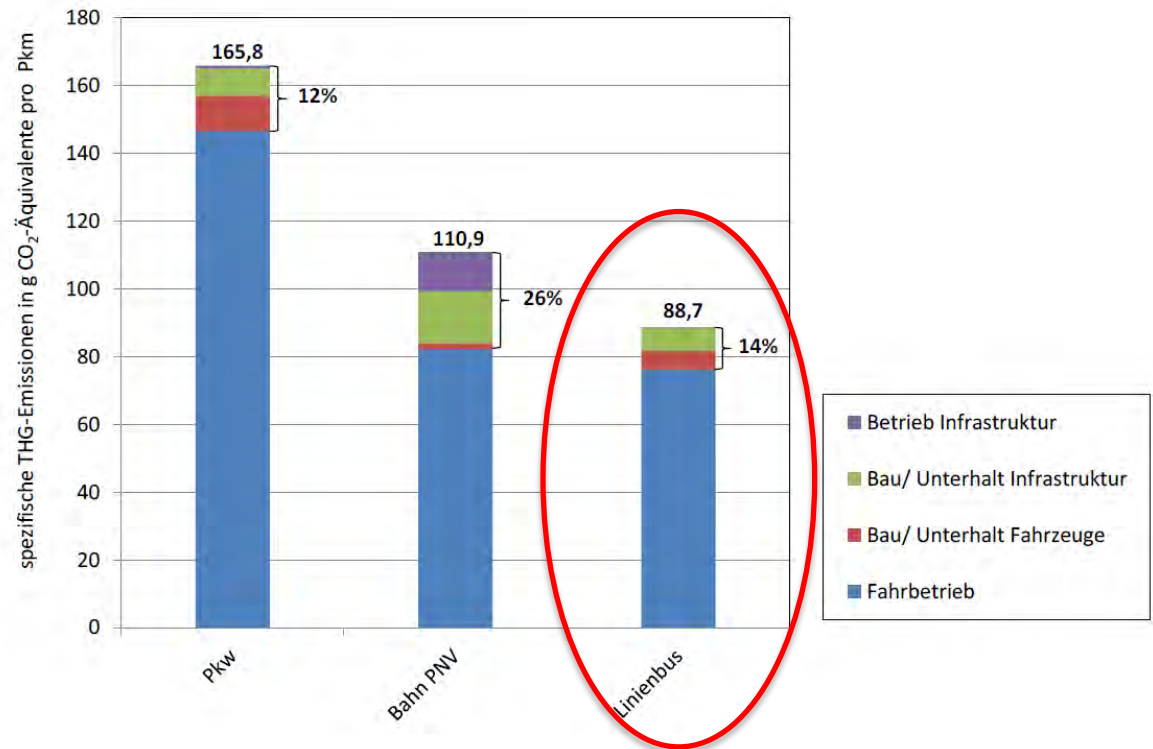




5. System comparison

5.1 Diesel Bus system

- Use of a study carried out by the Umweltbundesamt - Germany



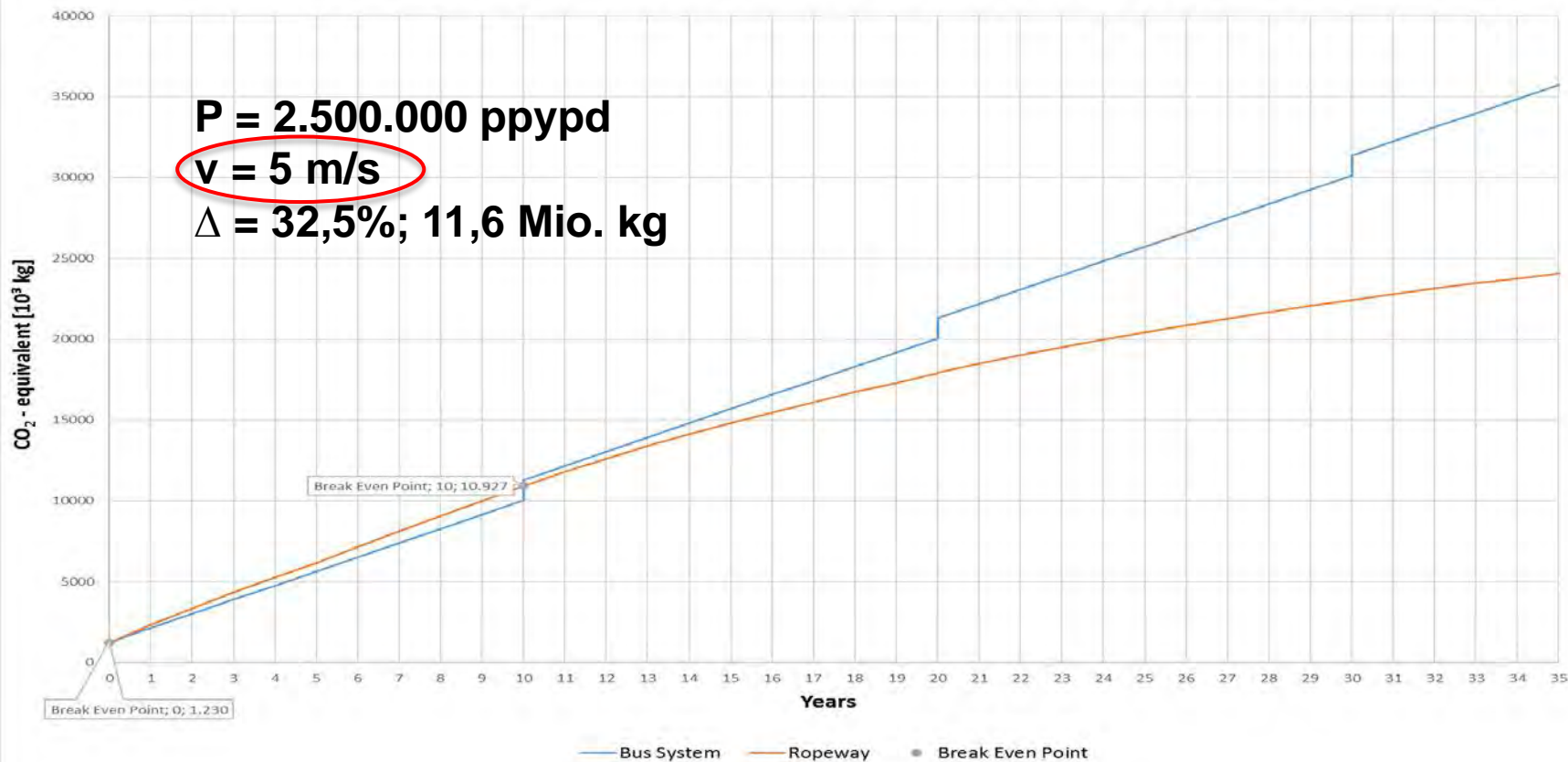
Average utilisation Bus system: 20%; Life time Bus system 10 years



5. System comparison

5.2 Example Yenimahalle – energy mix forecast DE

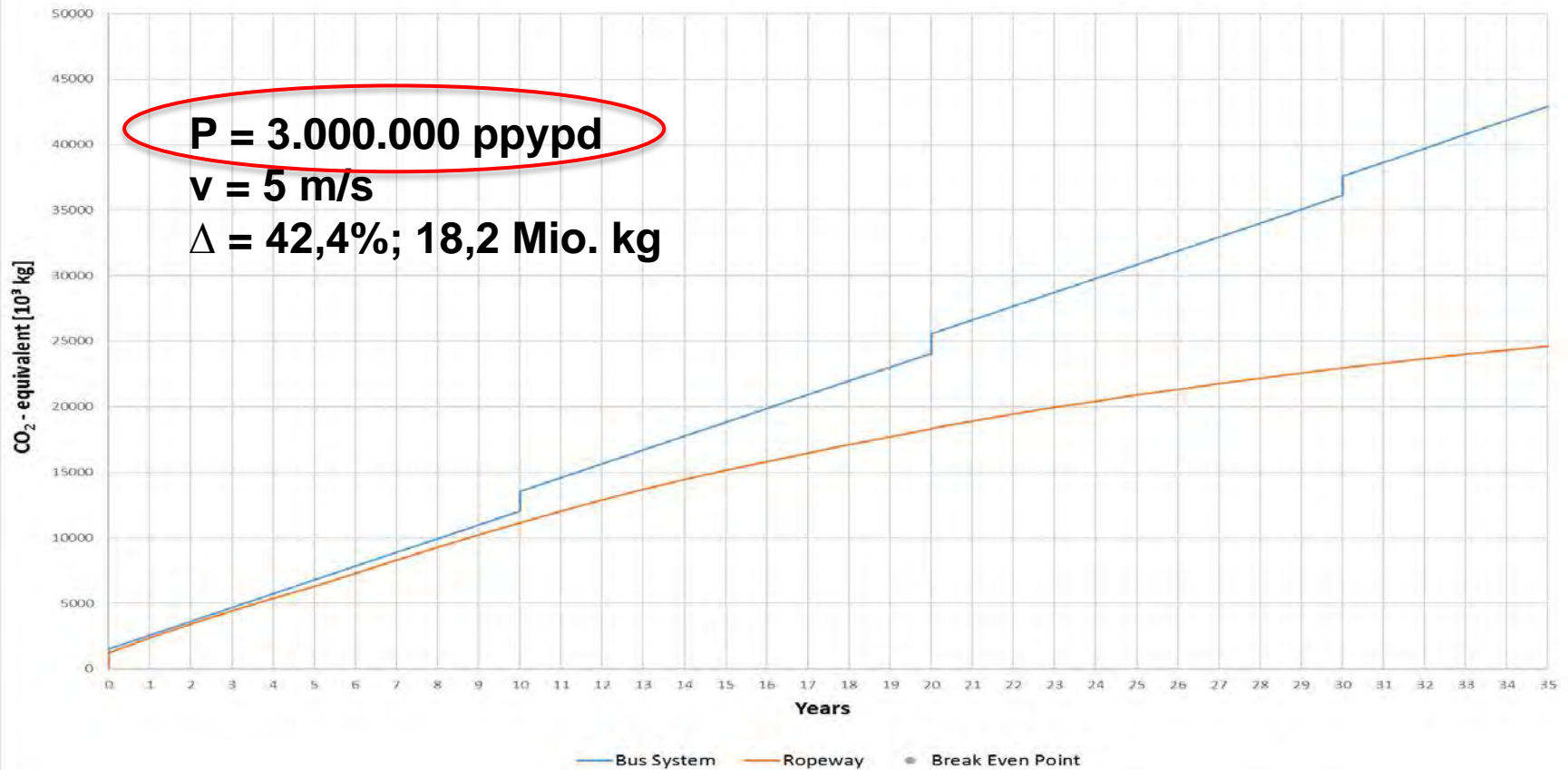
CO₂ - equivalent comparison Diesel Bus System - Ropeway



5. System comparison

5.3 Example Yenimahalle – energy mix forecast DE

CO₂ - equivalent comparison Diesel Bus System - Ropeway

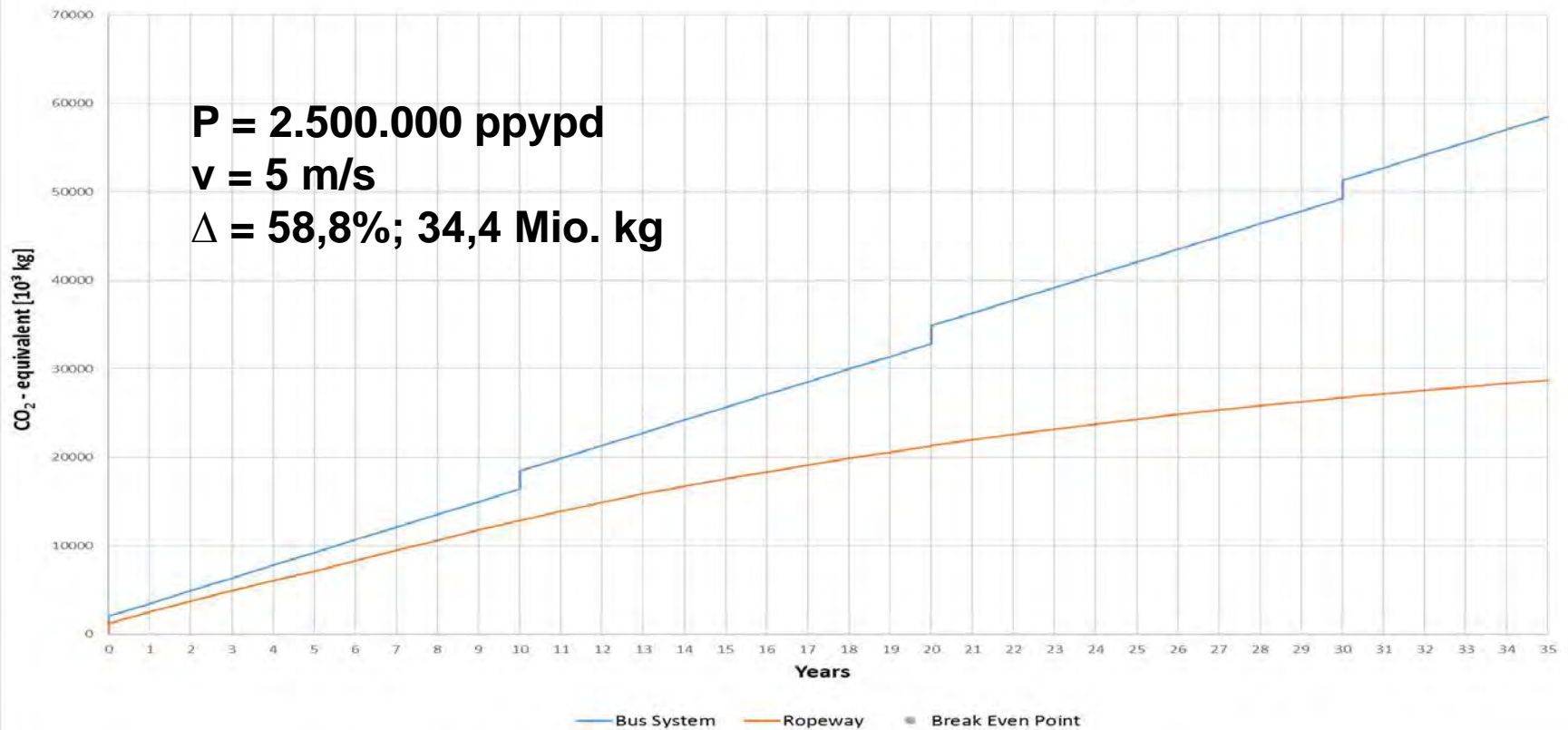


5. System comparison

5.4 Example Yenimahalle – energy mix forecast DE

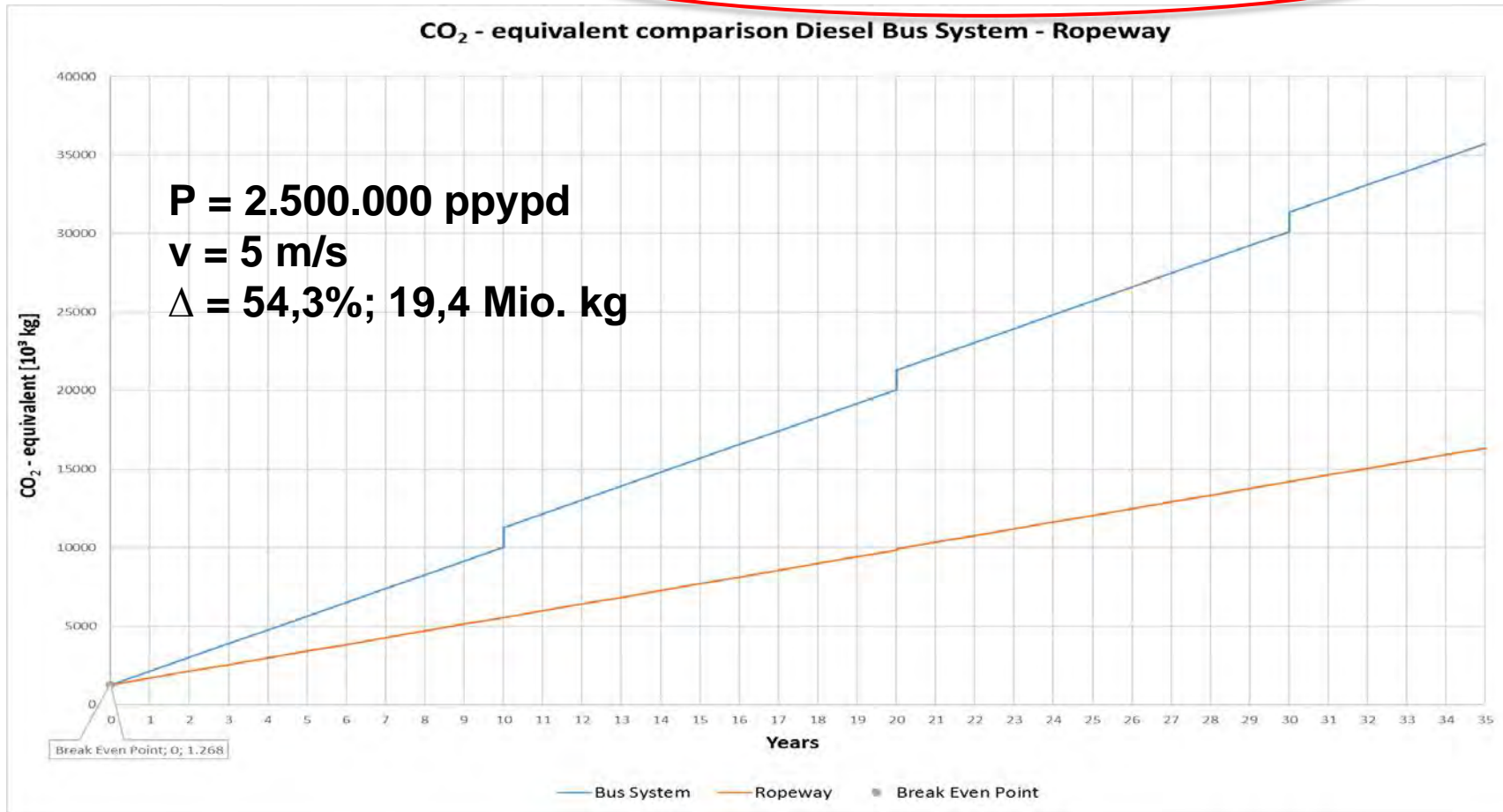
(length Bus line = 2x length Ropeway line)

CO₂ - equivalent comparison Diesel Bus System - Ropeway



5. System comparison

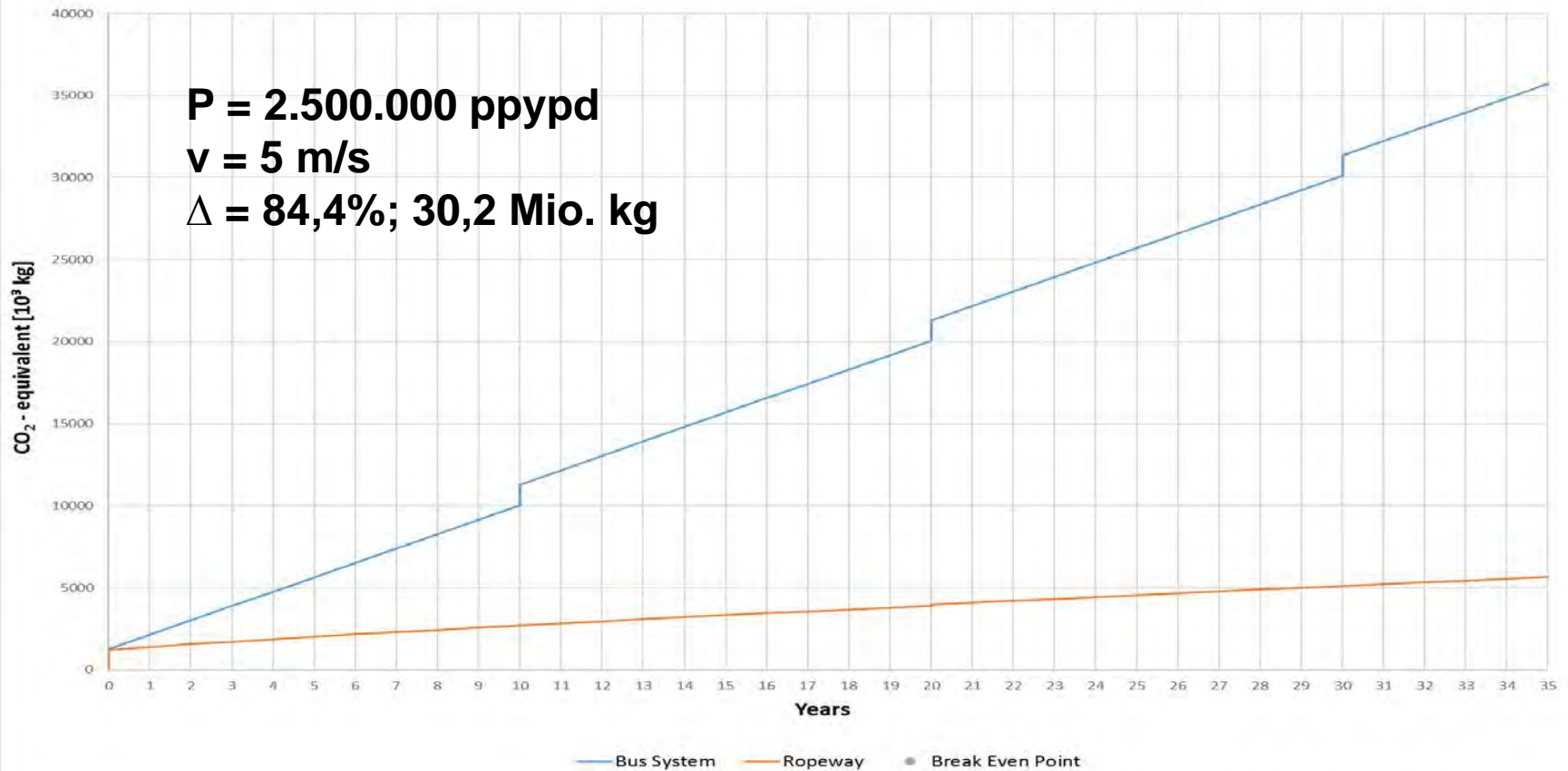
5.5 Example Yenimahalle – energy mix Austria 2015 (0,231 kg CO₂/kWh)



5. System comparison

5.6 Example Yenimahalle – green electricity forecast DE

CO₂ - equivalent comparison Diesel Bus System - Ropeway





5. System comparison

5.7 Future scenario „pure electromobility“:

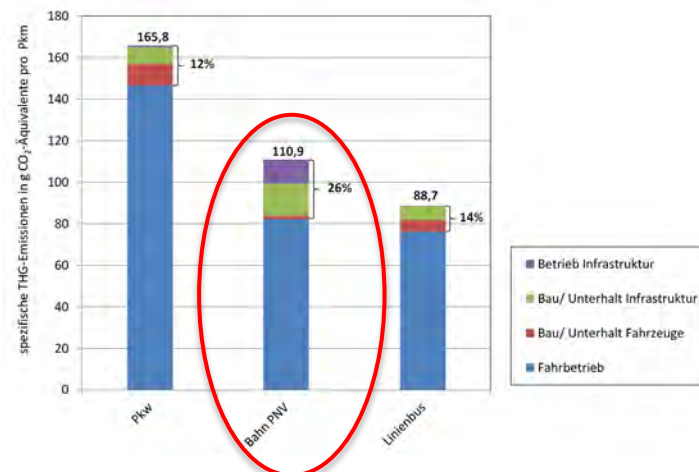
- Electromobility by battery powered busses
- Power generation by green electricity

Hypothesis: reduction CO₂ emissions bus proportional to energy production ratio

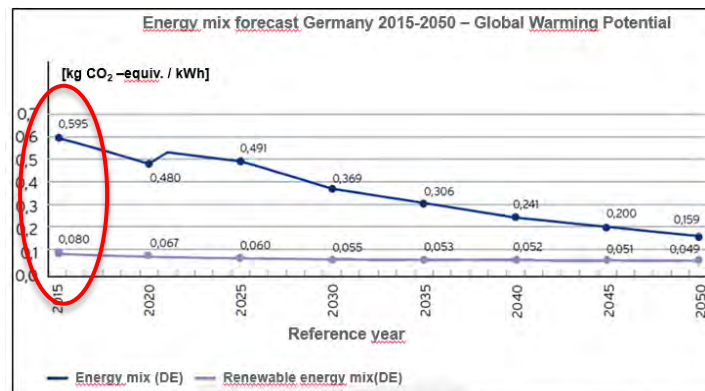
Electric tram (today) = 81 g CO₂ / km p

Electric Bus (tomorrow) = $81 * (0,080/0,595)$
= 10,9 g CO₂ / km p

⇒ Reduction CO₂ emissions of 86,5%



Source: Umweltbundesamt, Texte Nr. 96/2013

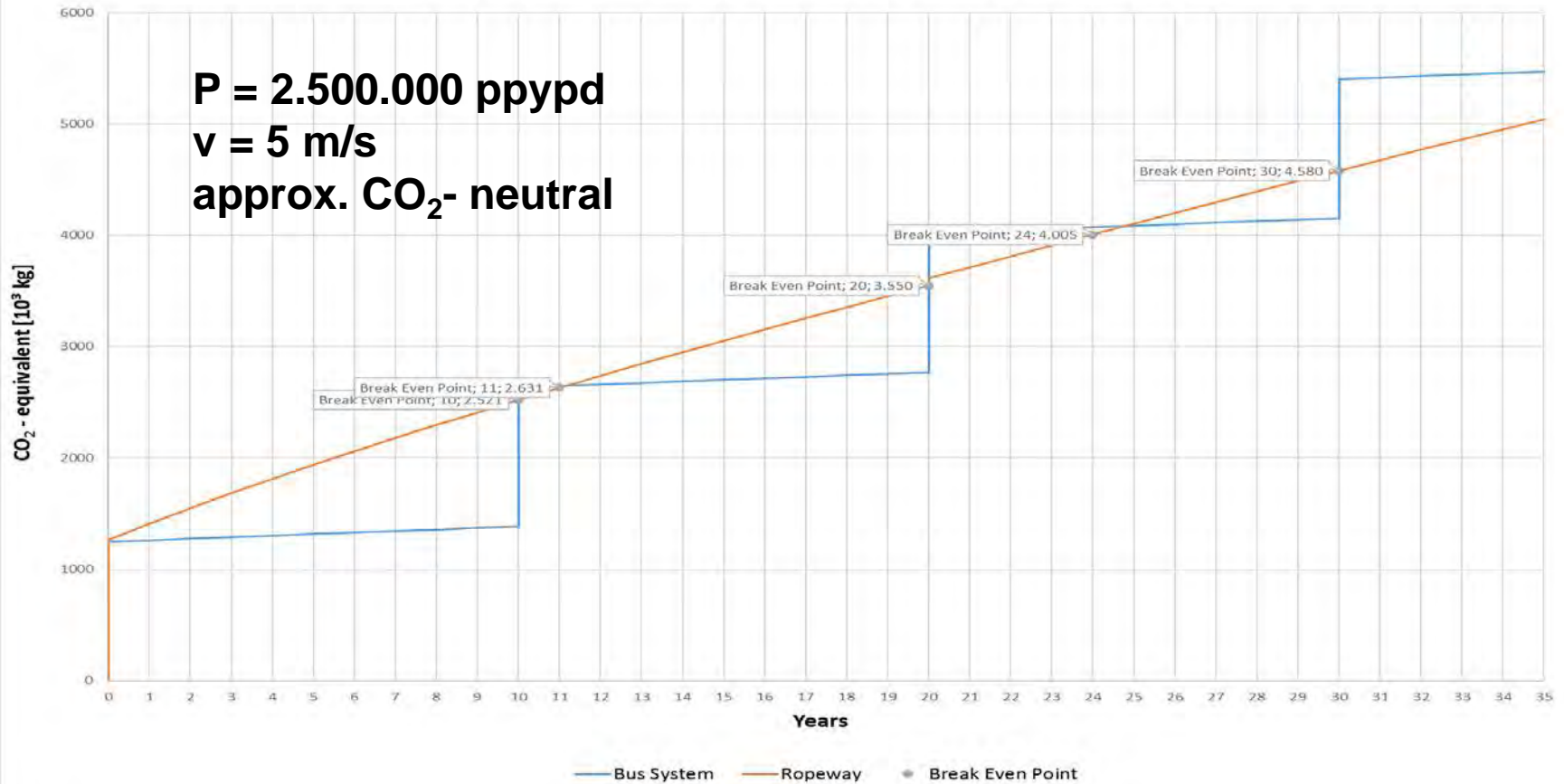


Source: BM für Verkehr und digitale Infrastruktur, 2016

5. System comparison

Example Yenimahalle – pure electromobility

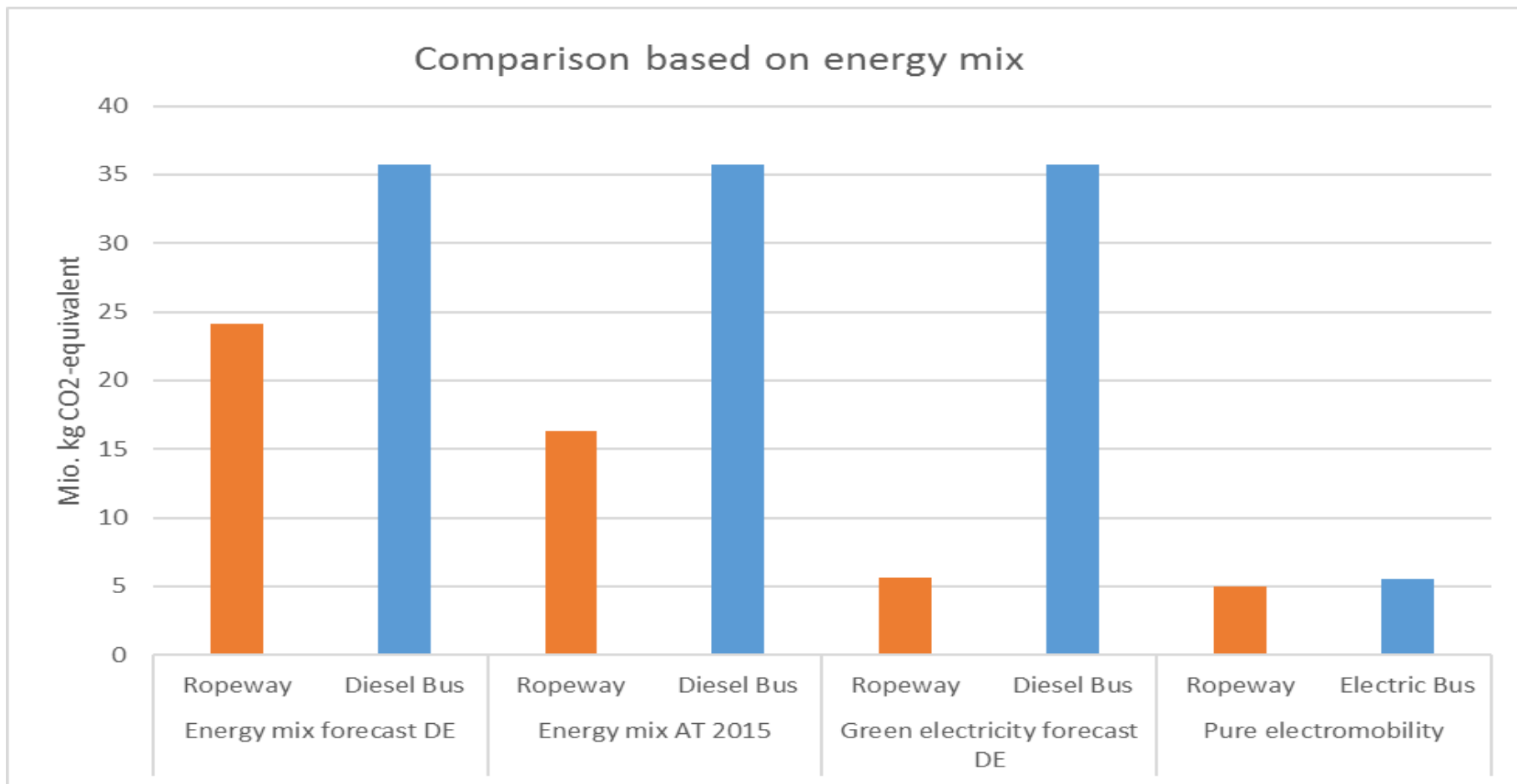
CO₂ - equivalent comparison Electric Bus System - Ropeway





5. System comparison

5.9 General considerations





6. Conclusion

6.1 Value of a Lifecycle Assessment

External Use:

- Basis for political decision makers
- Reduction of energy consumption and environmental footprint by optimized operation (= cost reduction!)
- International acceptance due to standardized method (ISO 14040)

Internal Use:

- Marketing, Communication
- Discover energy saving potentials, Process optimization
- Design for Life Cycle, Push of Innovation
- Motivation collaborators



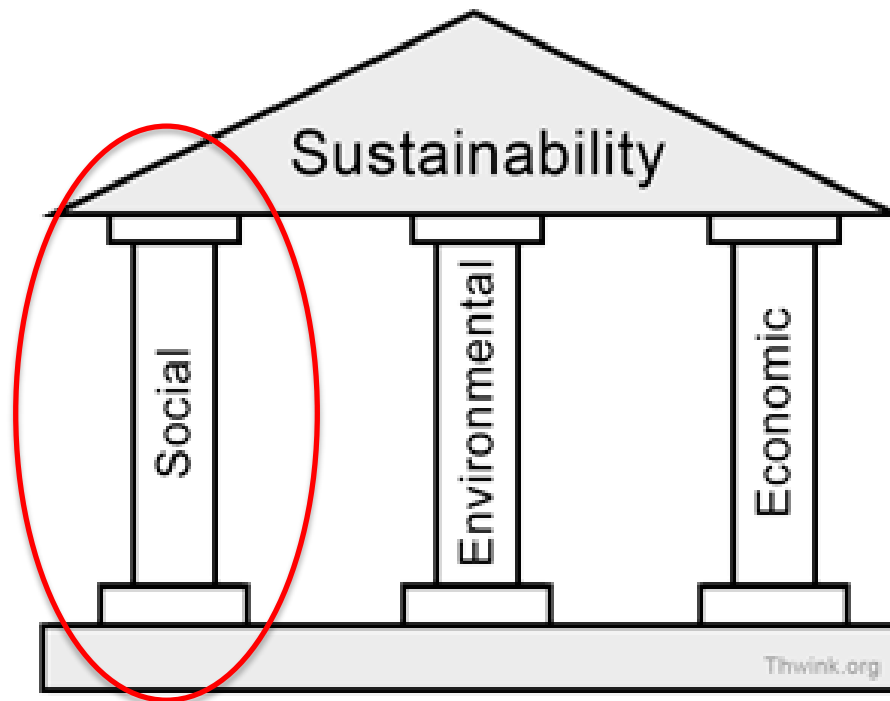
2013

GD10 Cambulos – Villamaria, Manizales / CO



6. Conclusion

6.2 Sustainability – social development





6. Conclusion

6.2 Sustainability – social development



Klaus Erharter
Florian Dörfler



6. Conclusion

6.2 Sustainability – social development



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