



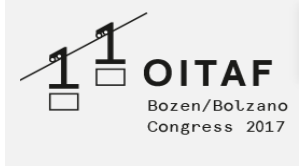
ECOLOGICAL FOOTPRINT OF A ROPEWAY INSTALLATION IN URBAN AREAS

Klaus Erharter



Ecological footprint of a ropeway installation in urban areas

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2. Lifecycle Assessment (LCA) - Methodology
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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

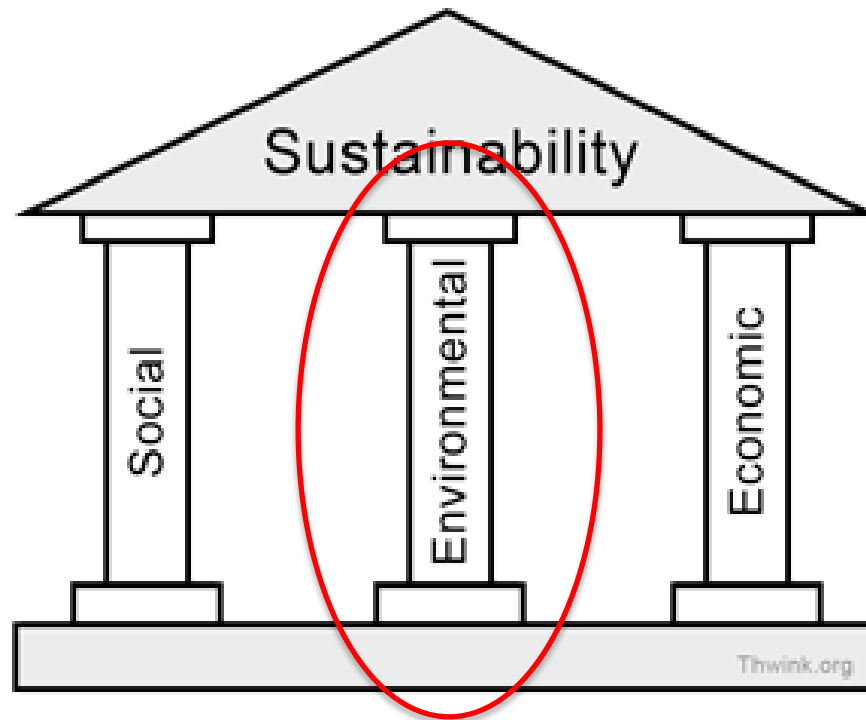
at the local, national and global levels.“





1. Introduction

1.2 Three pillars model

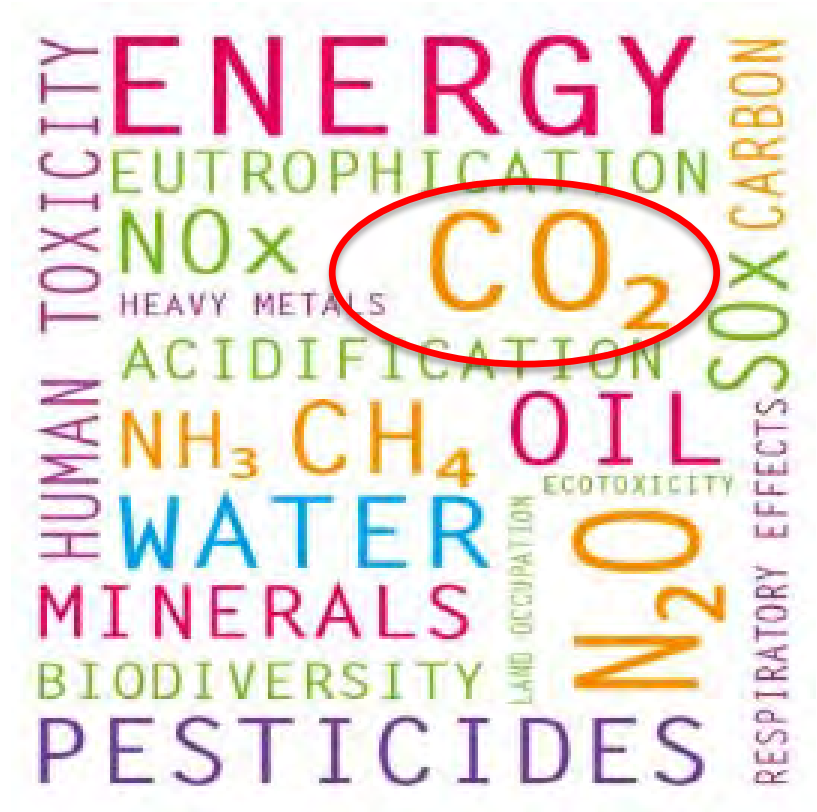




1. Introduction

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

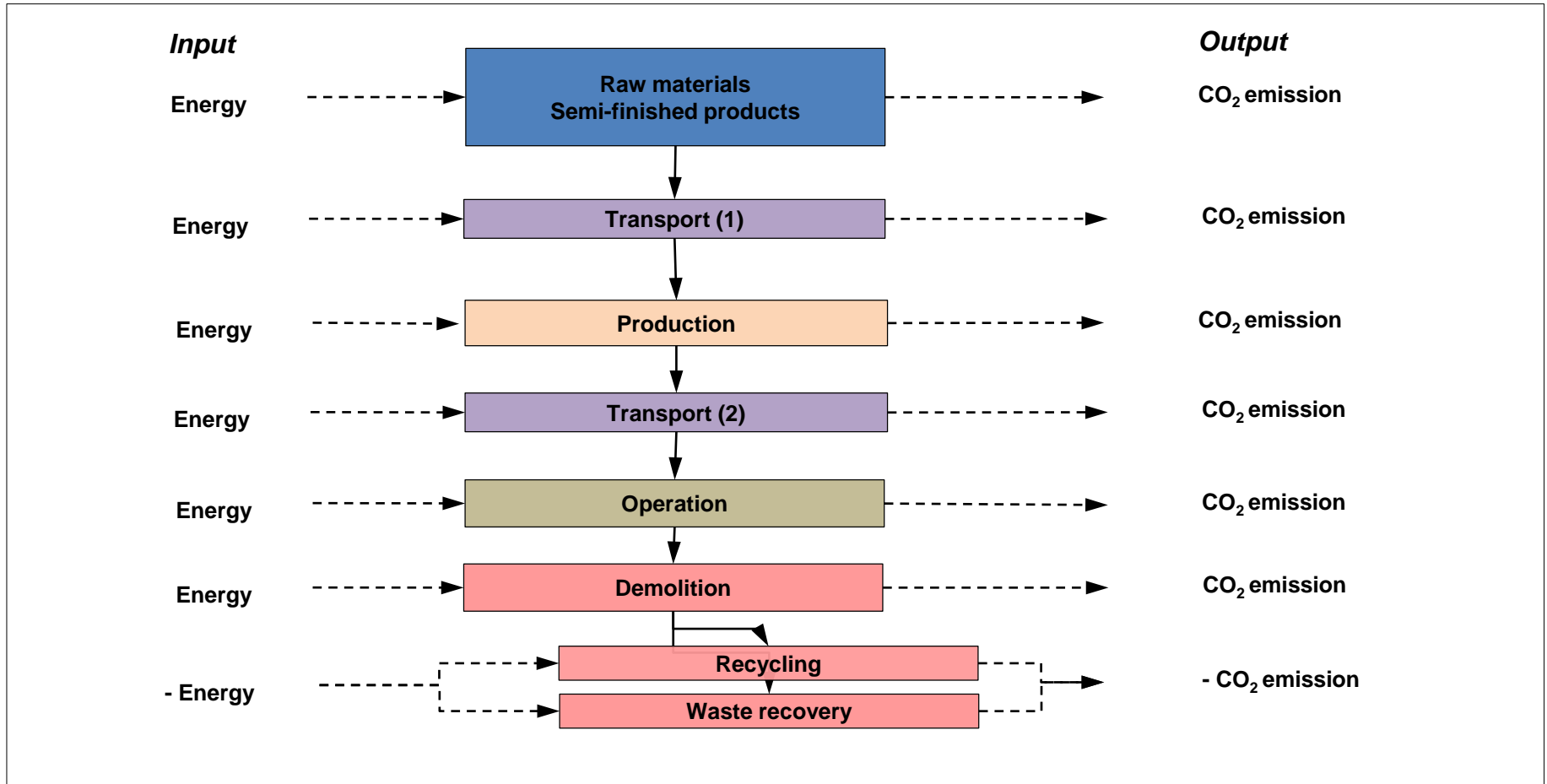
2.1 Ecological footprint – a lifecycle analysis





2. Lifecycle Assessment (LCA) - Methodology

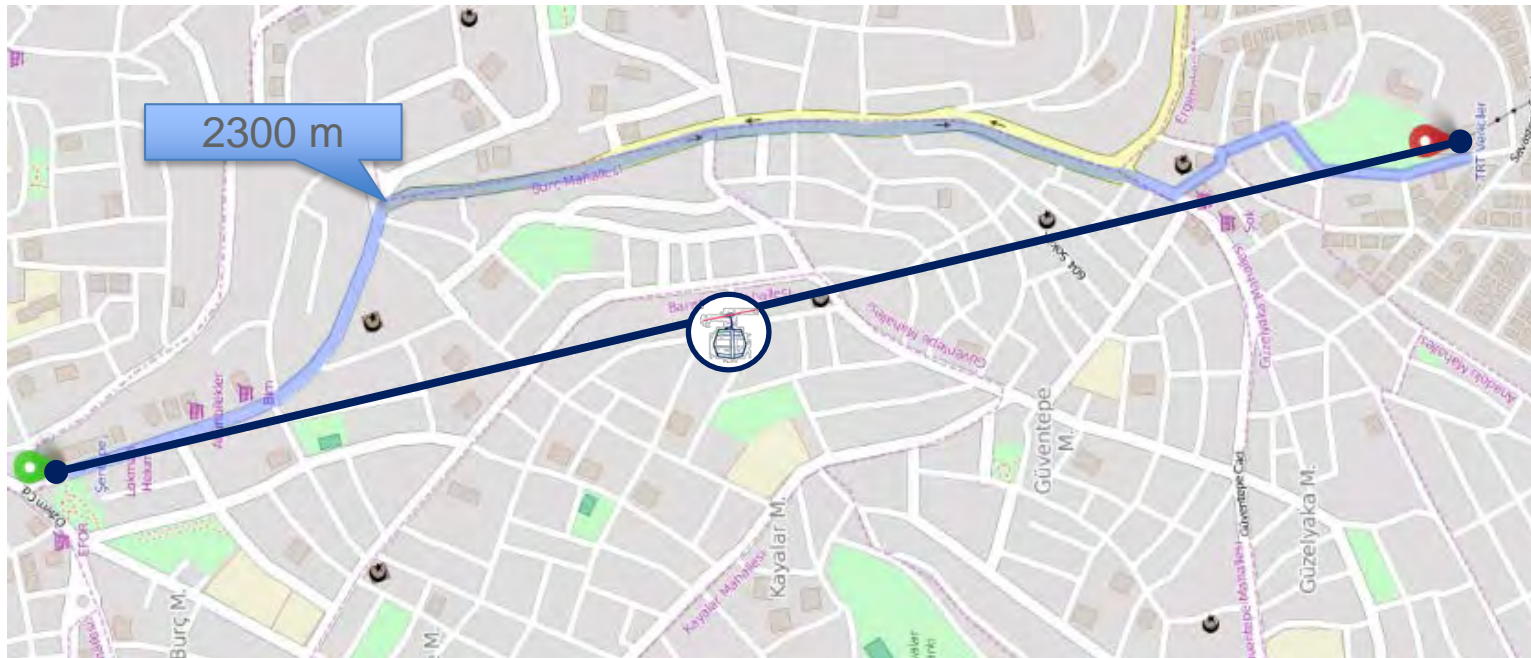
2.2 LCA – Set of unit processes within the product system











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]

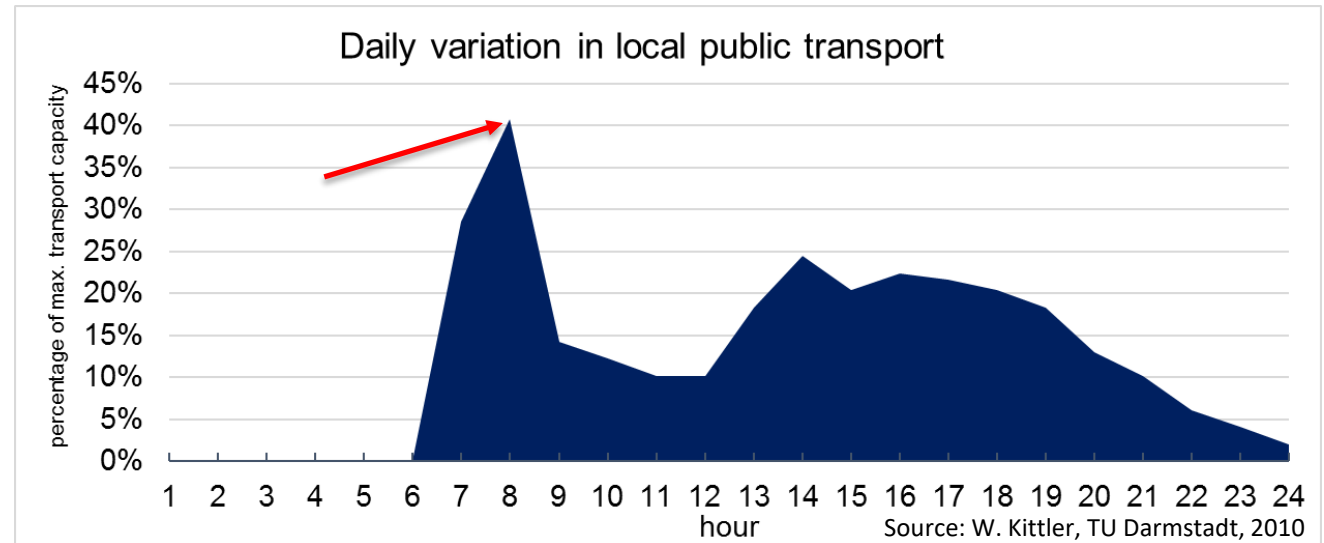
-  35 years
-  1881,7 m
-  75 m
-  2400 pphpd
-  315 – 425 kW
-  88 p
-  9 p



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

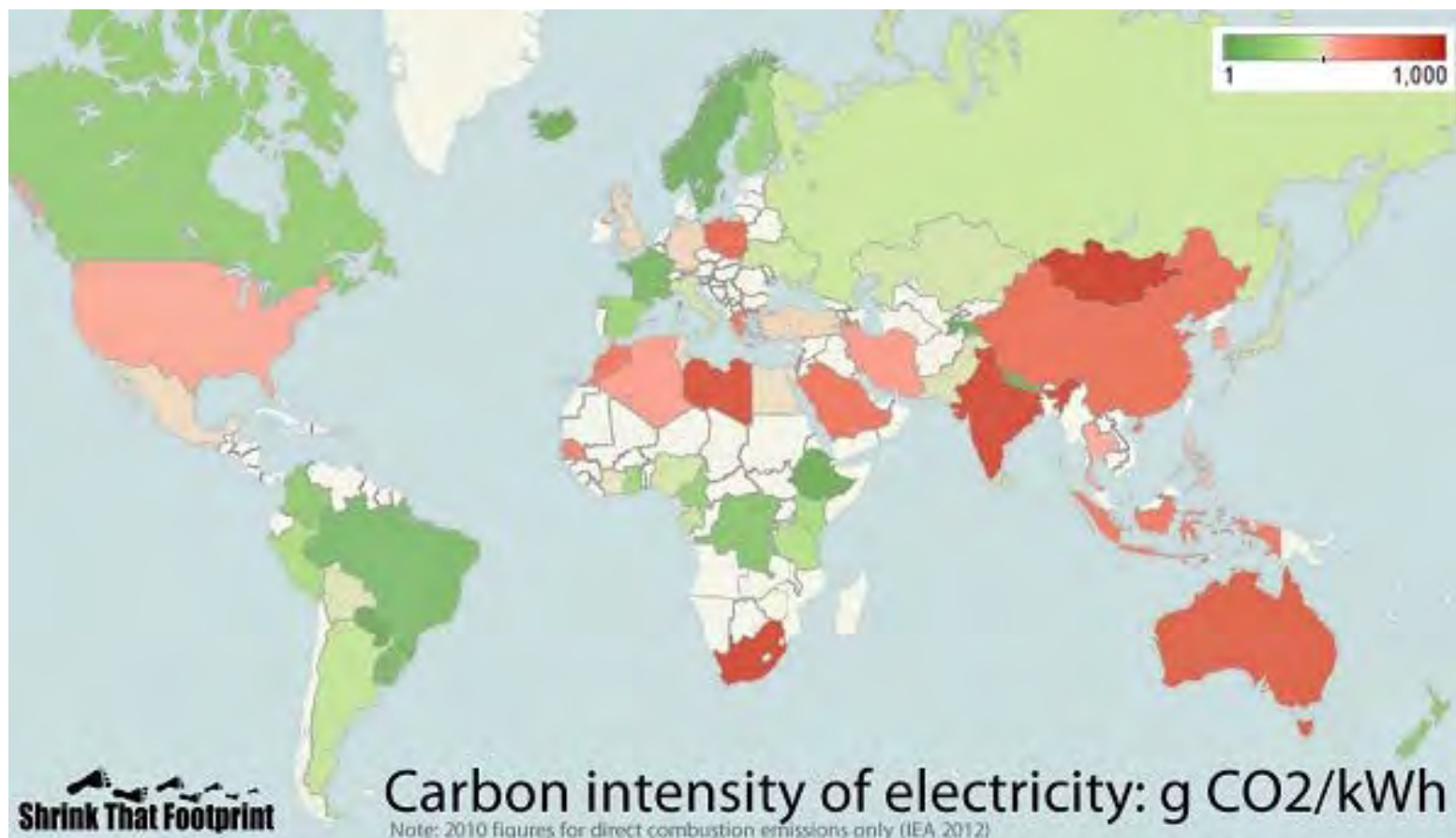
4.2 Calculation model – operation of the ropeway

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

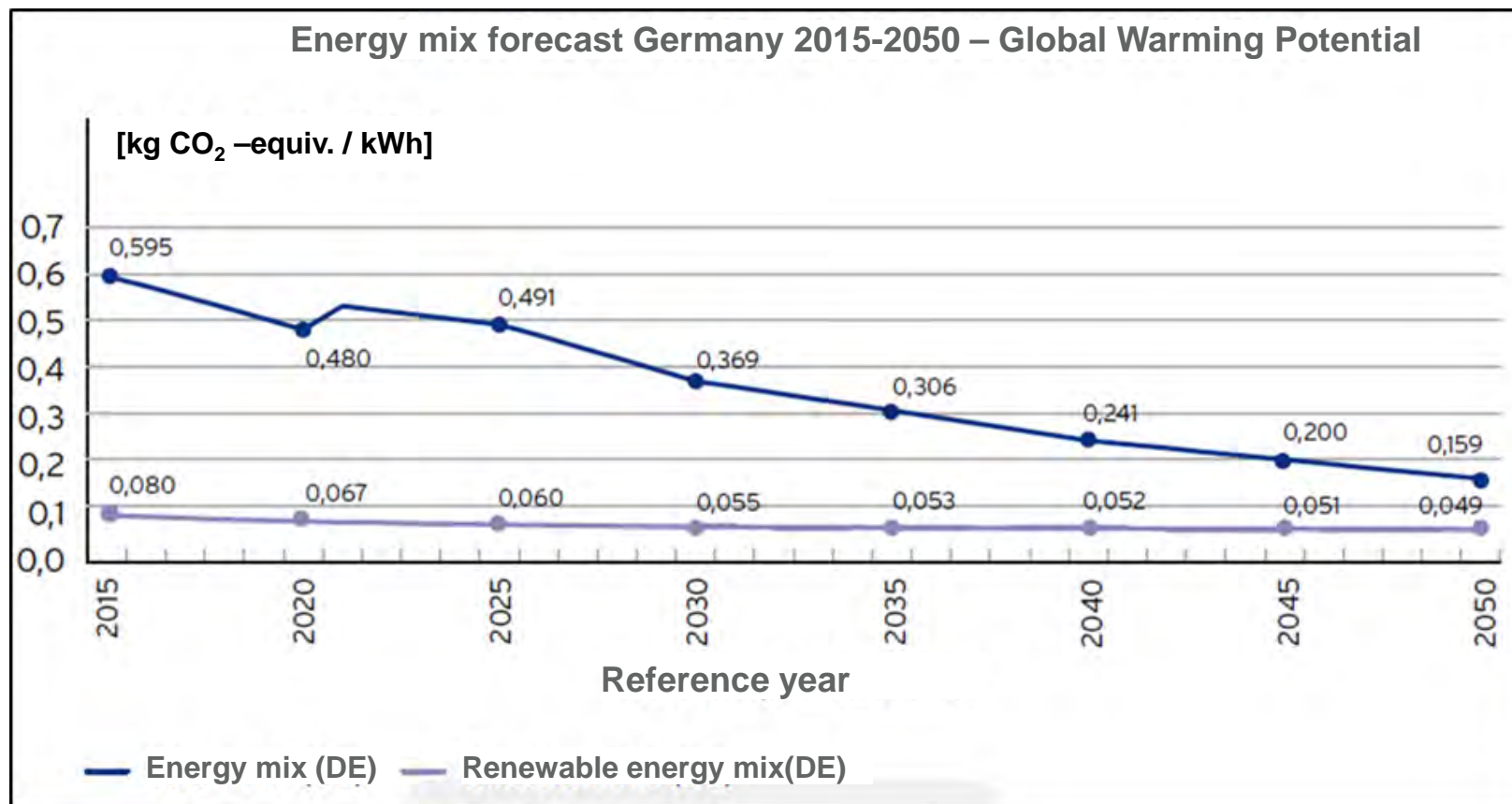


Source: greenbiz.it



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)

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

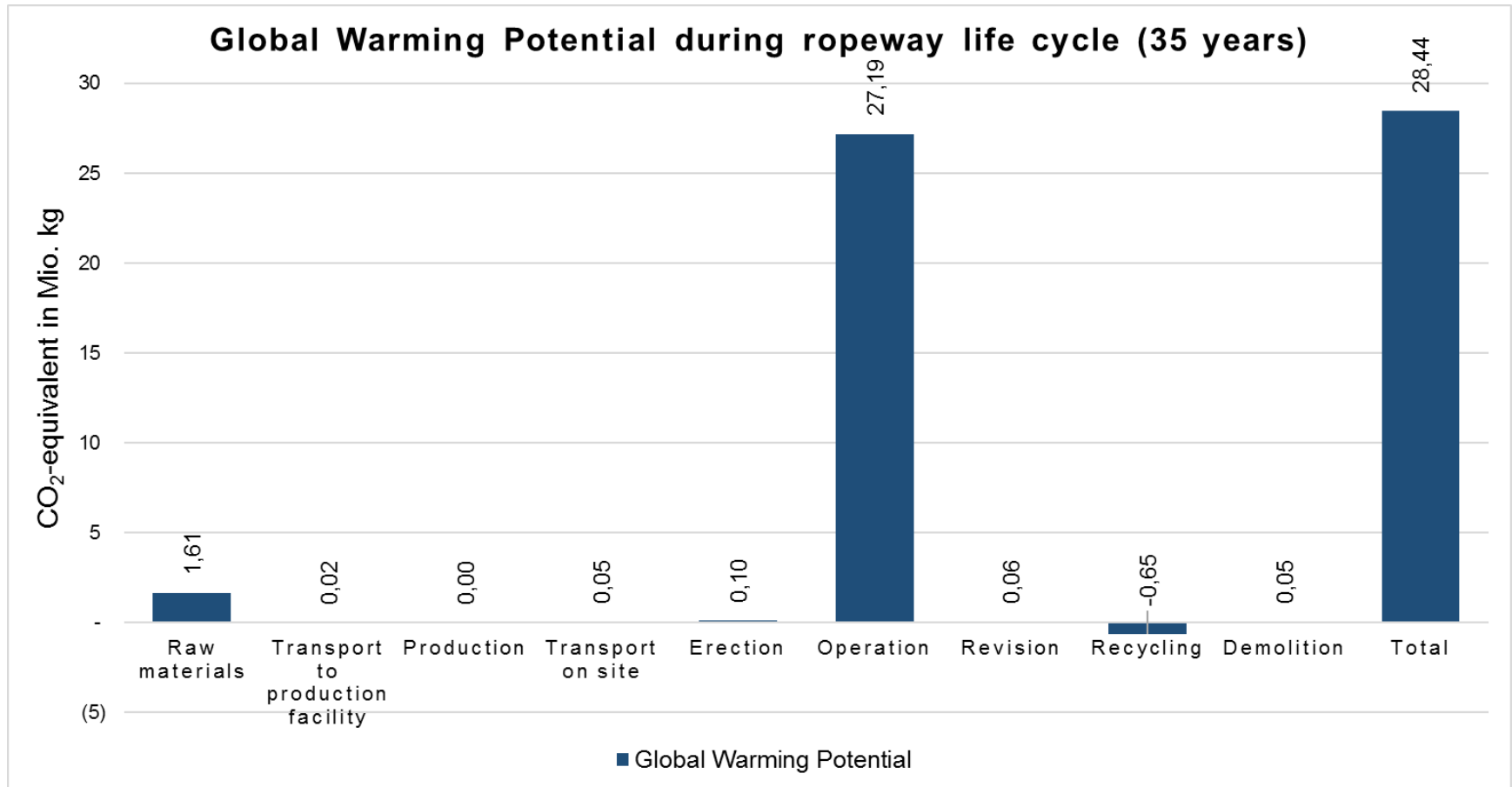
Example

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



4. Data sources and calculation model

4.3 Results

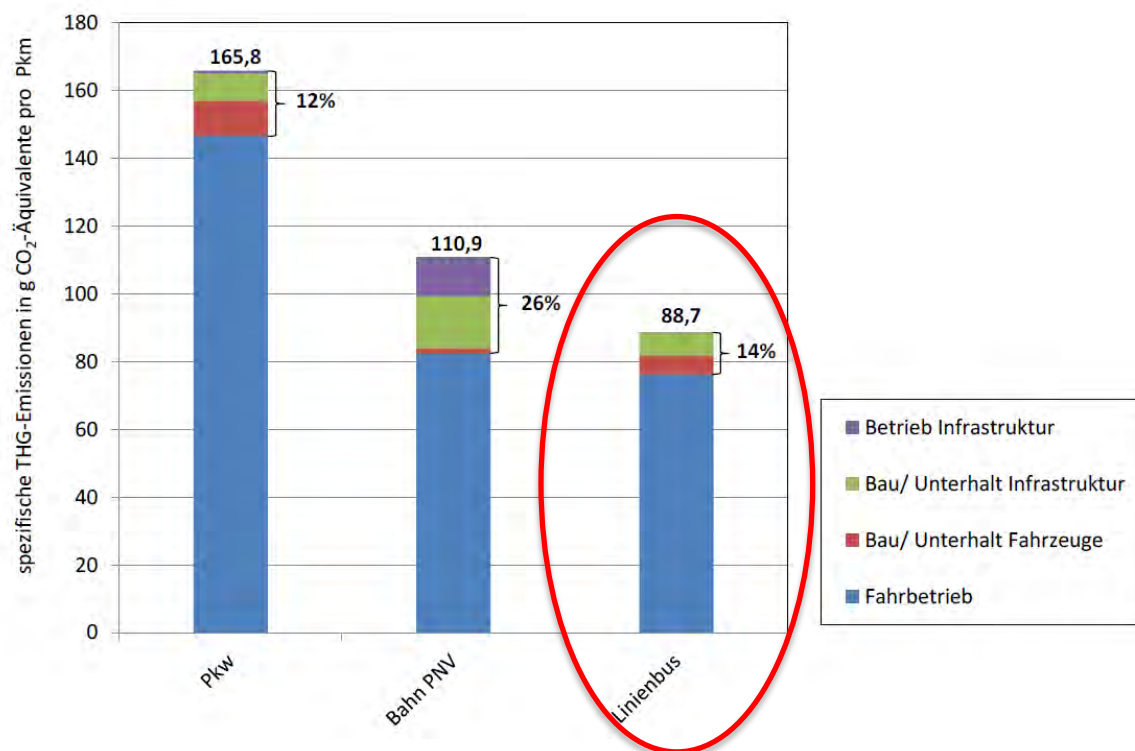




5. System comparison

5.1 Diesel Bus system

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



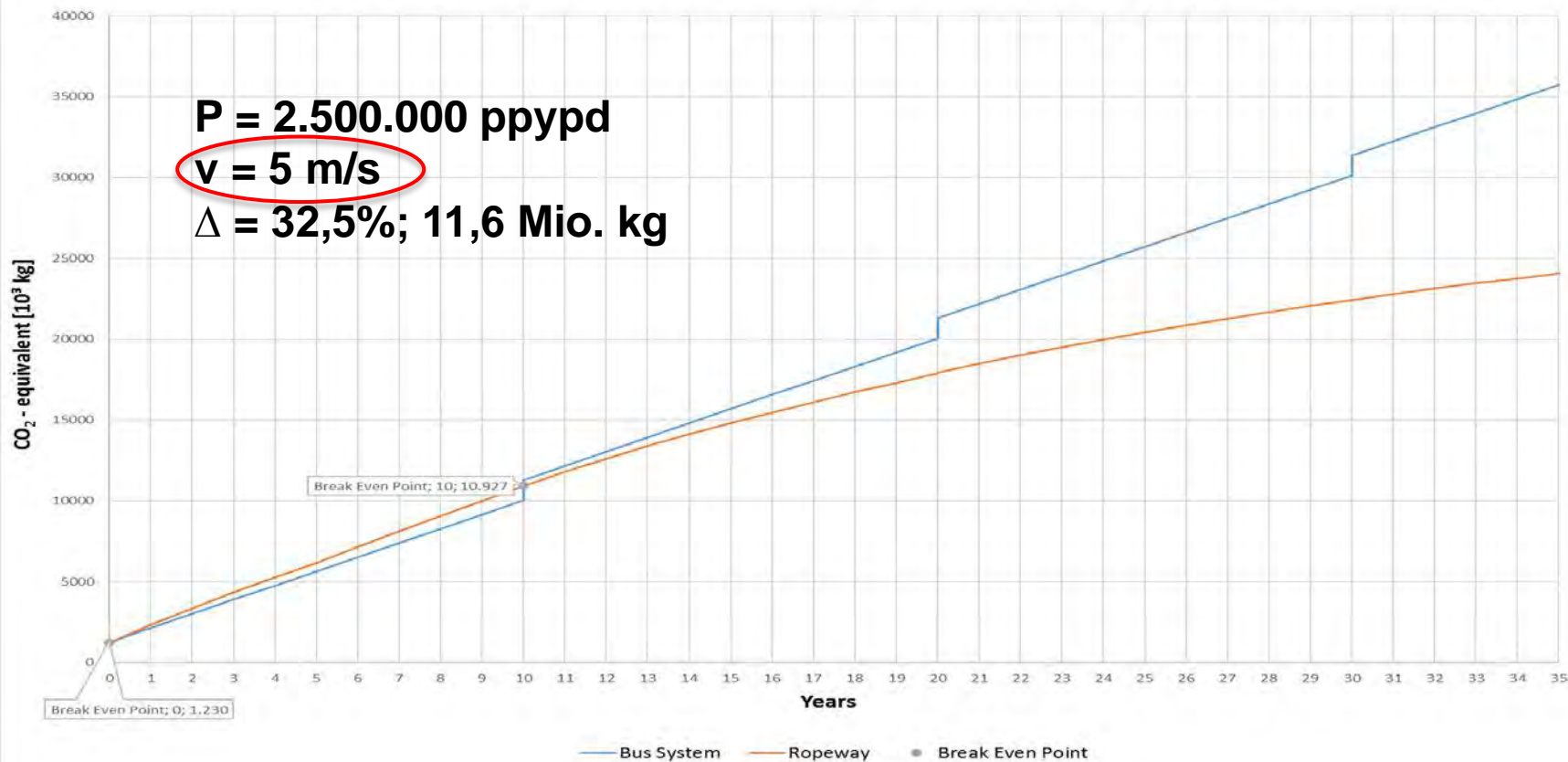
Average utilisation Bus system: 20%; Life time Bus system 10 years



5. System comparison

5.2 Example Yenimahalle – energy mix forecast DE

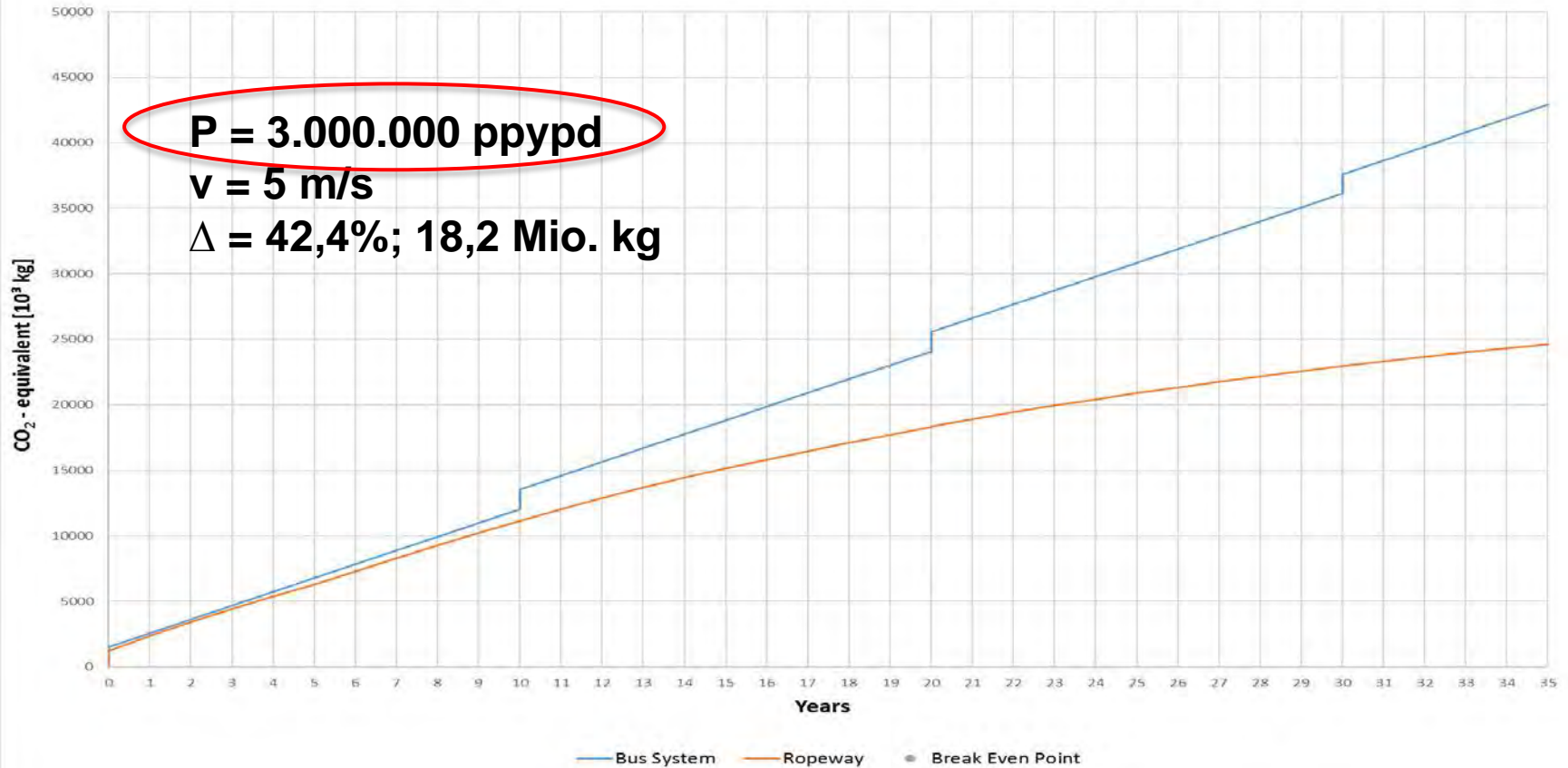
CO₂ - equivalent comparison Diesel Bus System - Ropeway



5. System comparison

5.3 Example Yenimahalle – energy mix forecast DE

CO₂ - equivalent comparison Diesel Bus System - Ropeway

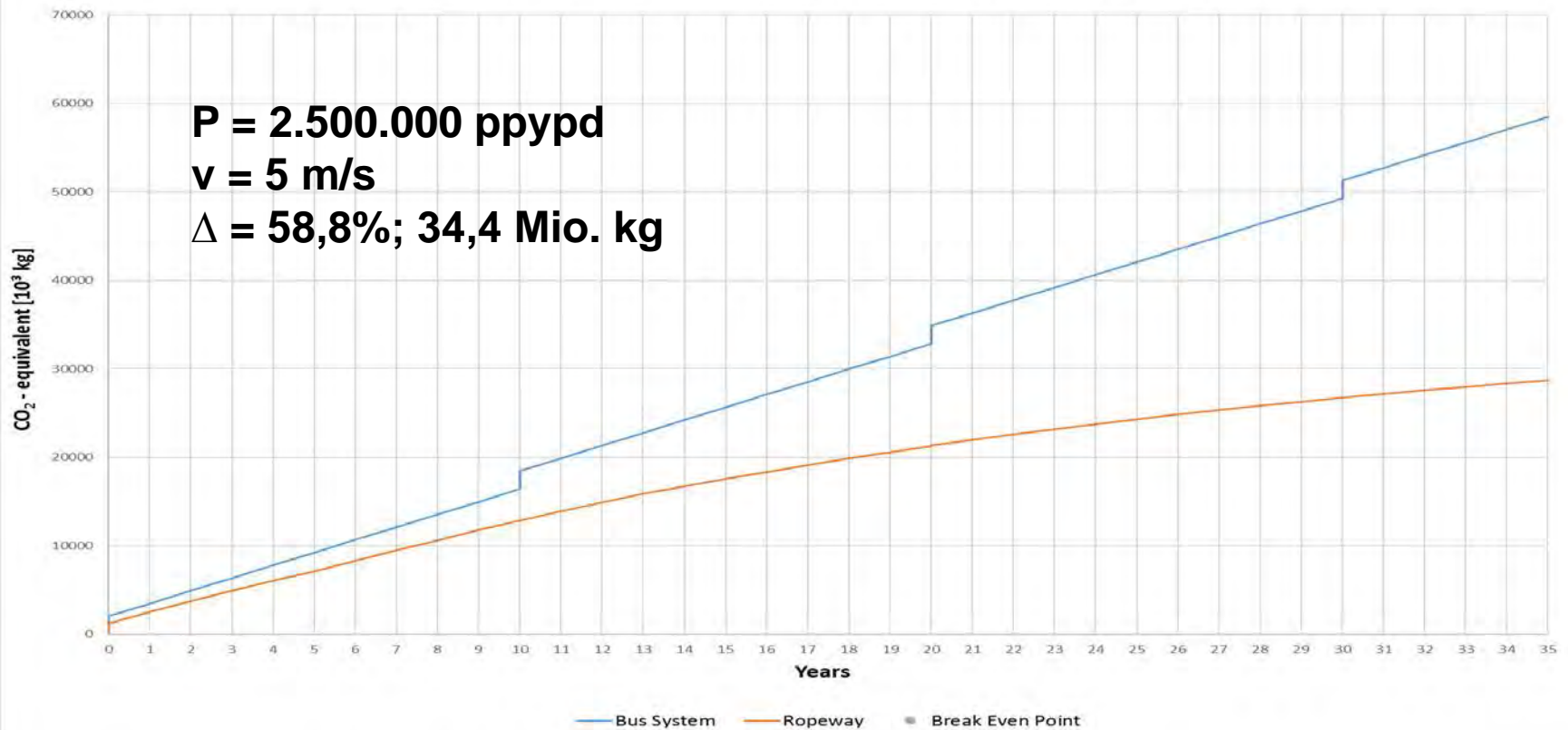


5. System comparison

5.4 Example Yenimahalle – energy mix forecast DE

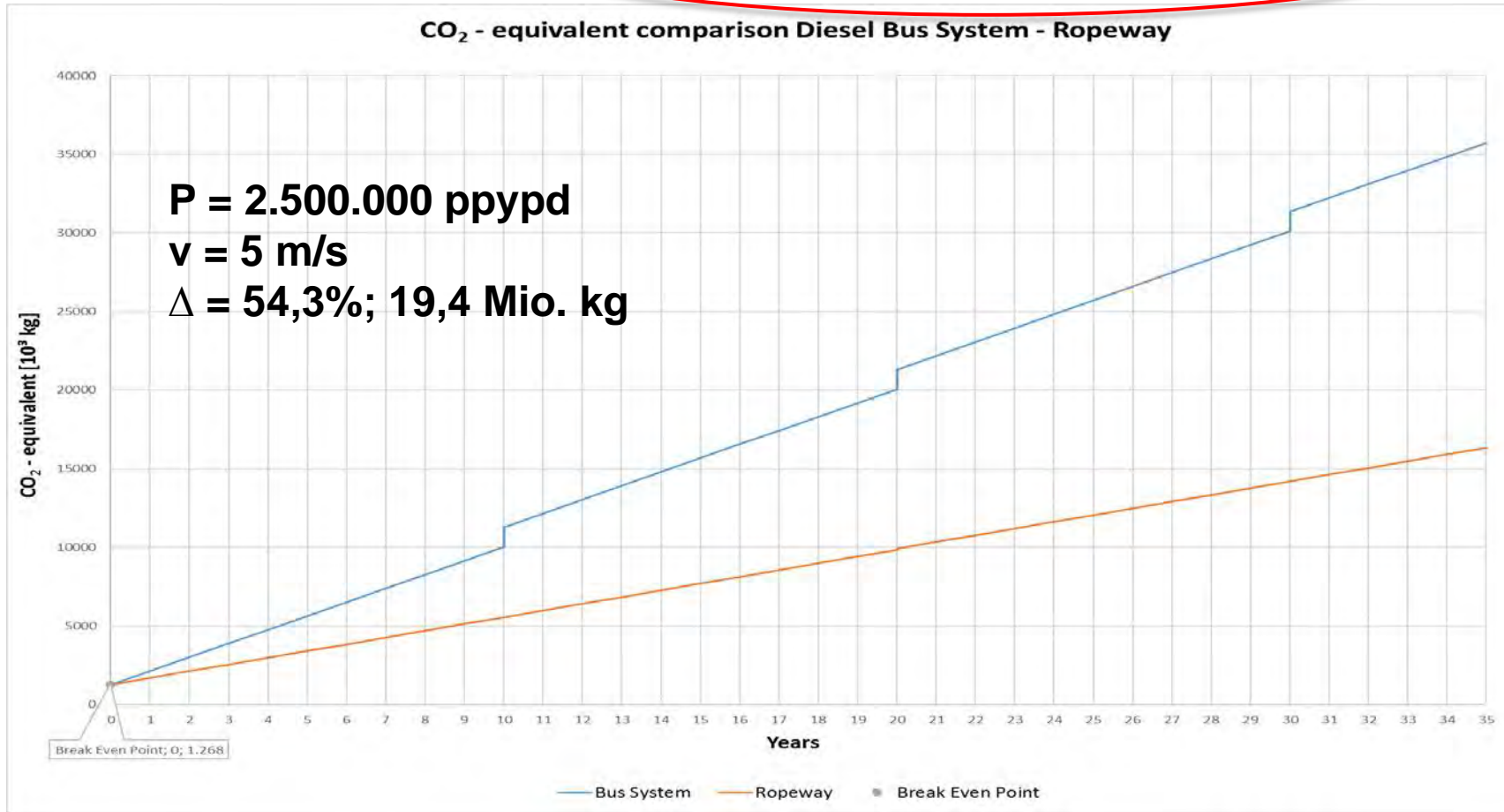
(length Bus line = 2x length Ropeway line)

CO₂ - equivalent comparison Diesel Bus System - Ropeway



5. System comparison

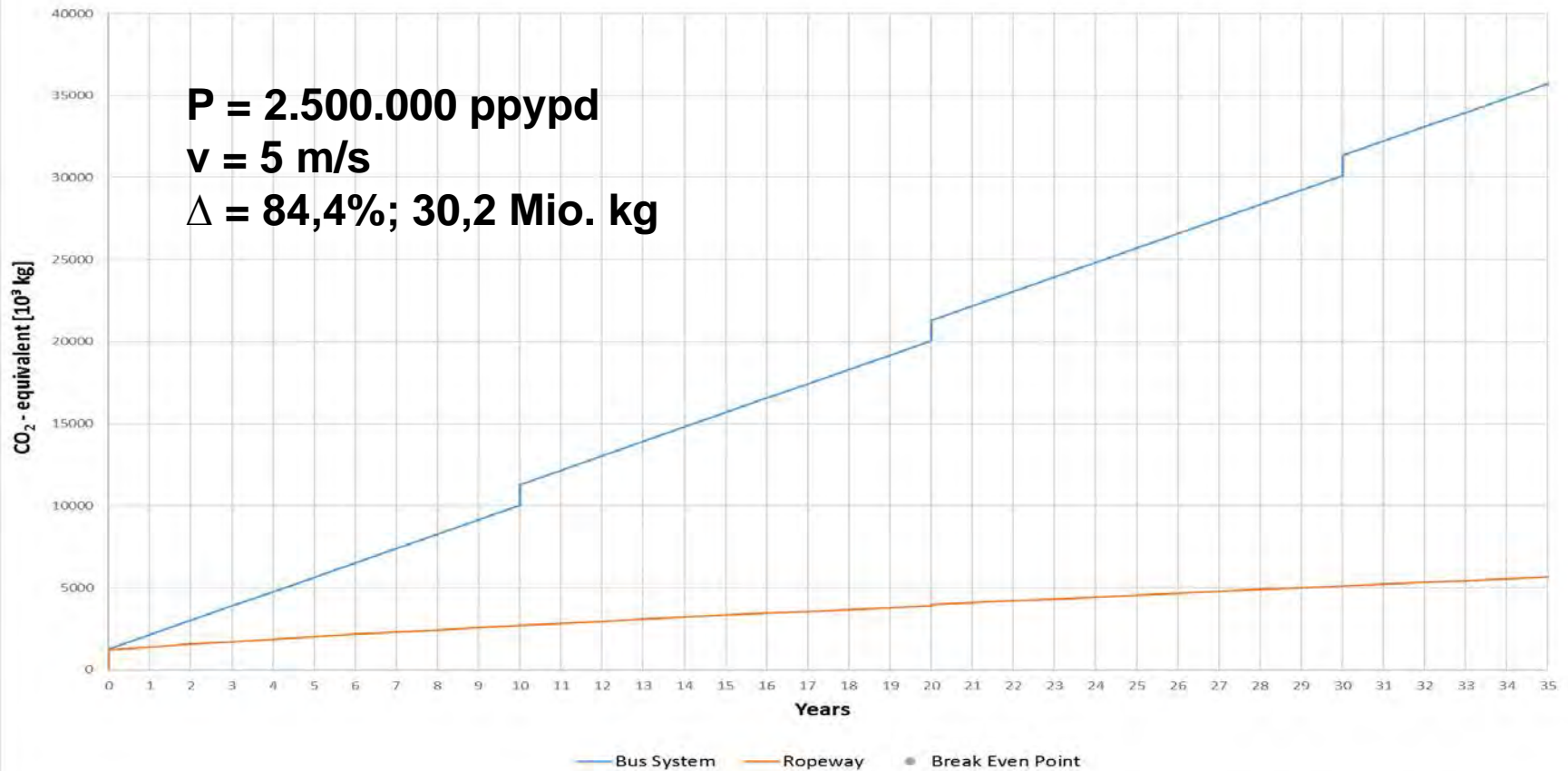
5.5 Example Yenimahalle – energy mix Austria 2015 (0,231 kg CO₂/kWh)



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“:

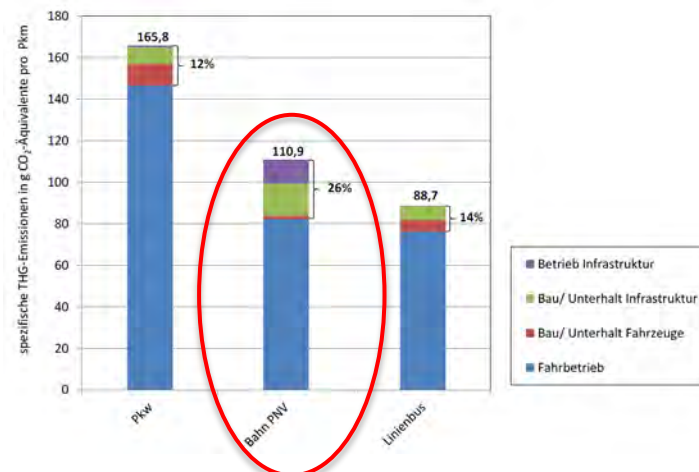
- Electromobility by battery powered busses
- Power generation by green electricity

Hypothesis: reduction CO₂ emissions bus proportional to energy production ratio

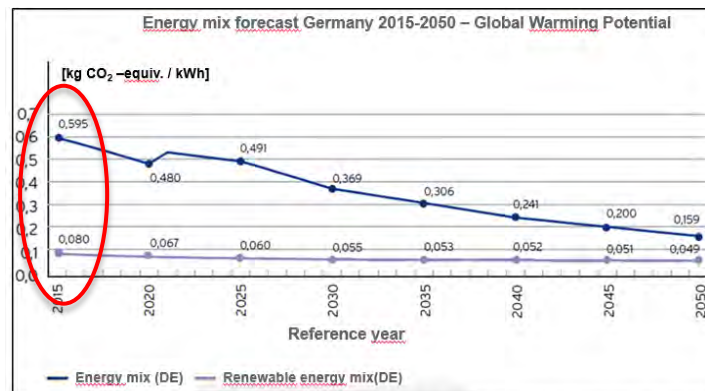
Electric tram (today) = 81 g CO₂ / km p

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

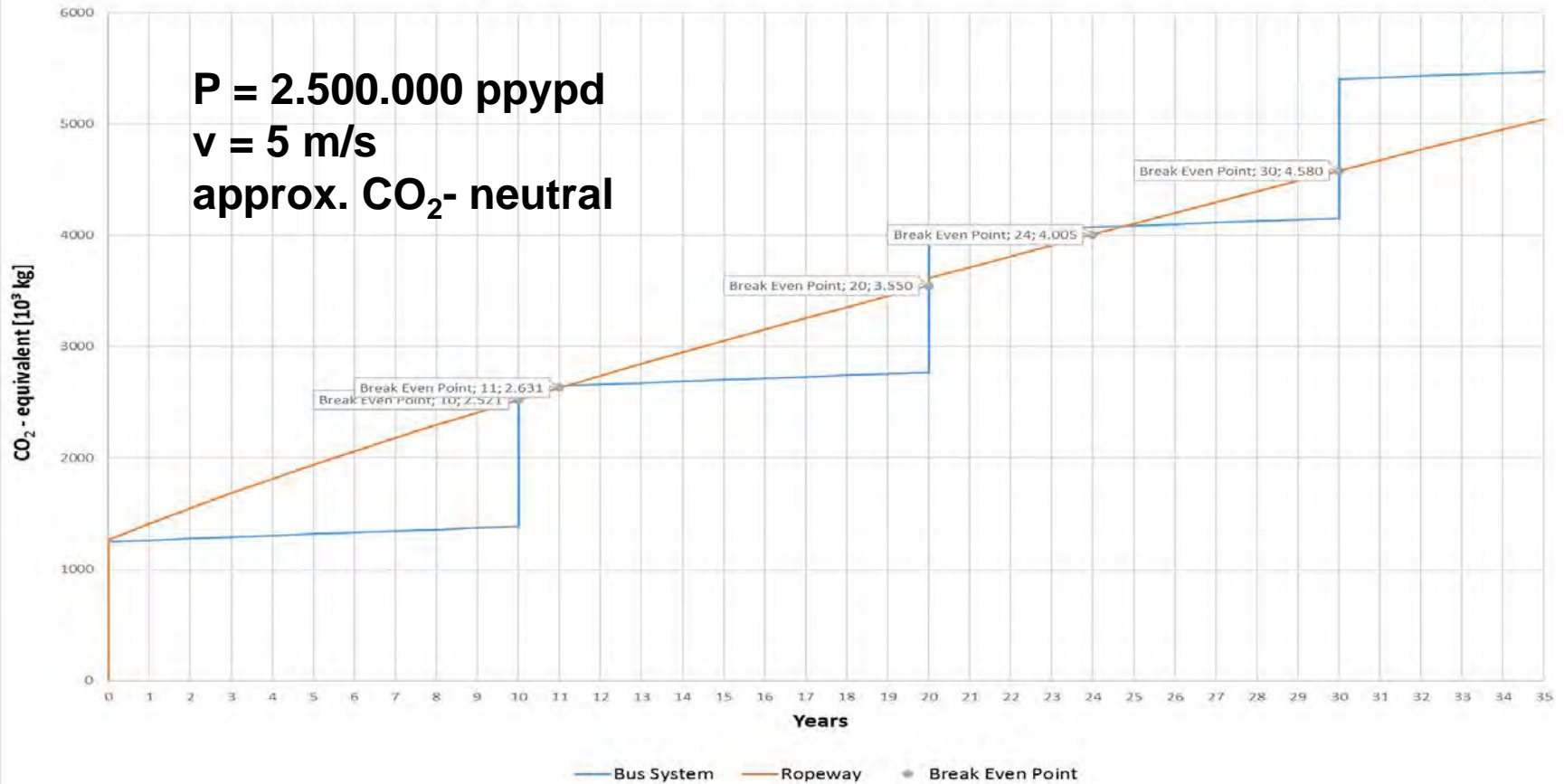


Source: BM für Verkehr und digitale Infrastruktur, 2016

5. System comparison

Example Yenimahalle – pure electromobility

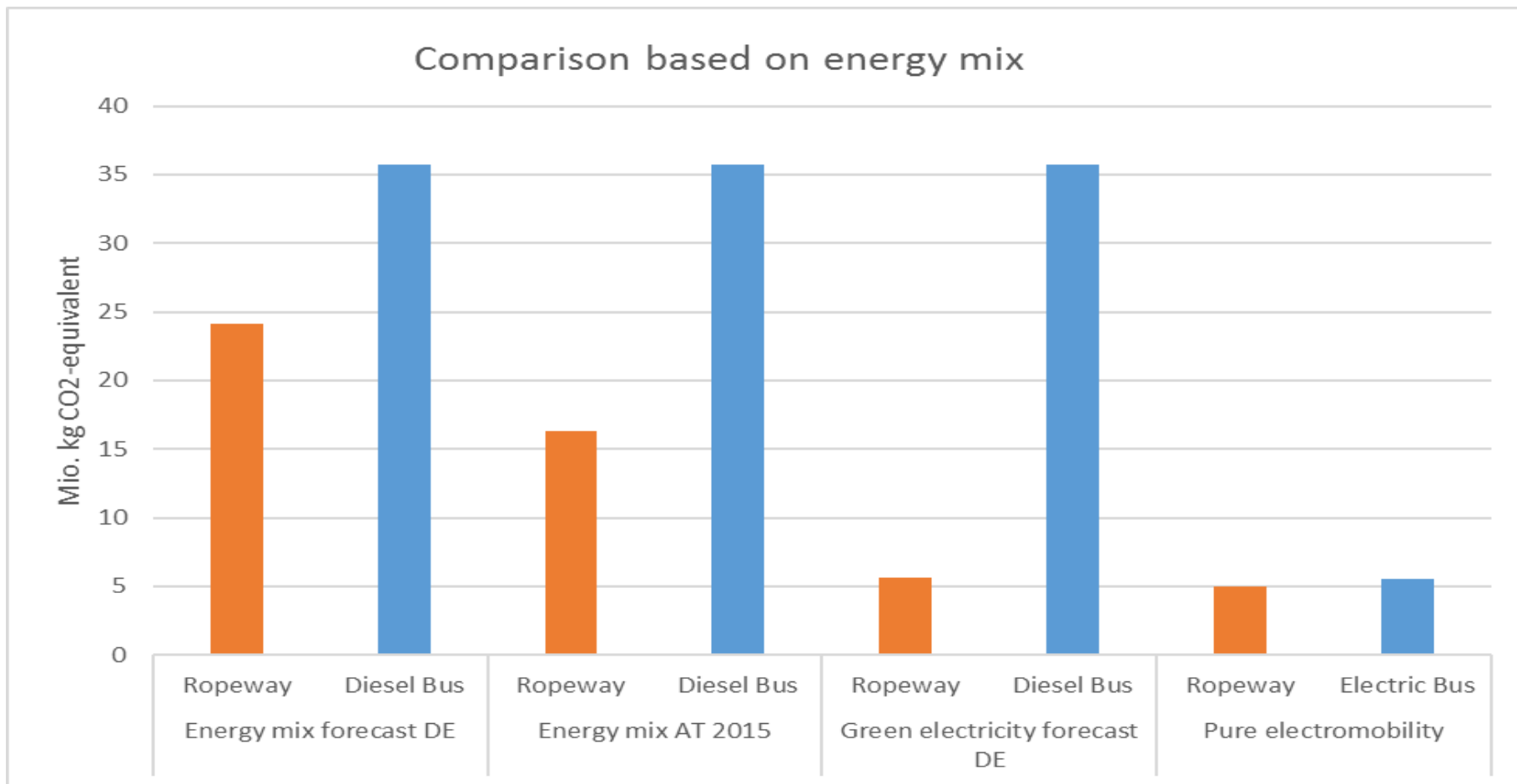
CO₂ - equivalent comparison Electric Bus System - Ropeway





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



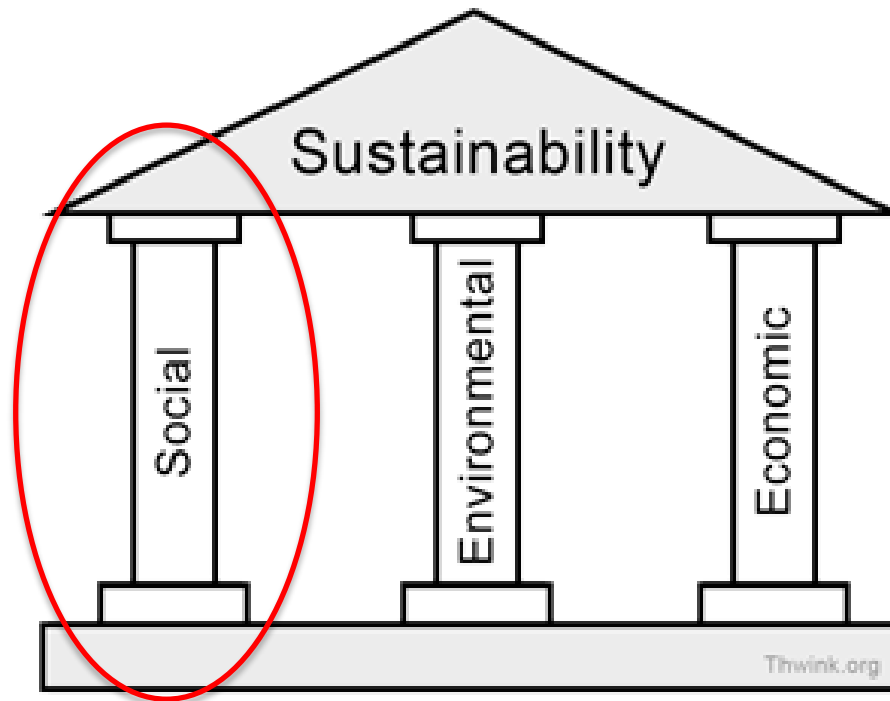
2013

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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