ECOLOGICAL FOOTPRINT OF A ROPEWAY INSTALLATION IN URBAN AREAS

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Ecological footprint of a ropeway installation in urban areas

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Florian Dörfler

OITAF
Bozen/Bolzano
Congress 2017

Fraunhofer IBP
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hochschule hof
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LEITNER® ropeways

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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) --

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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.“

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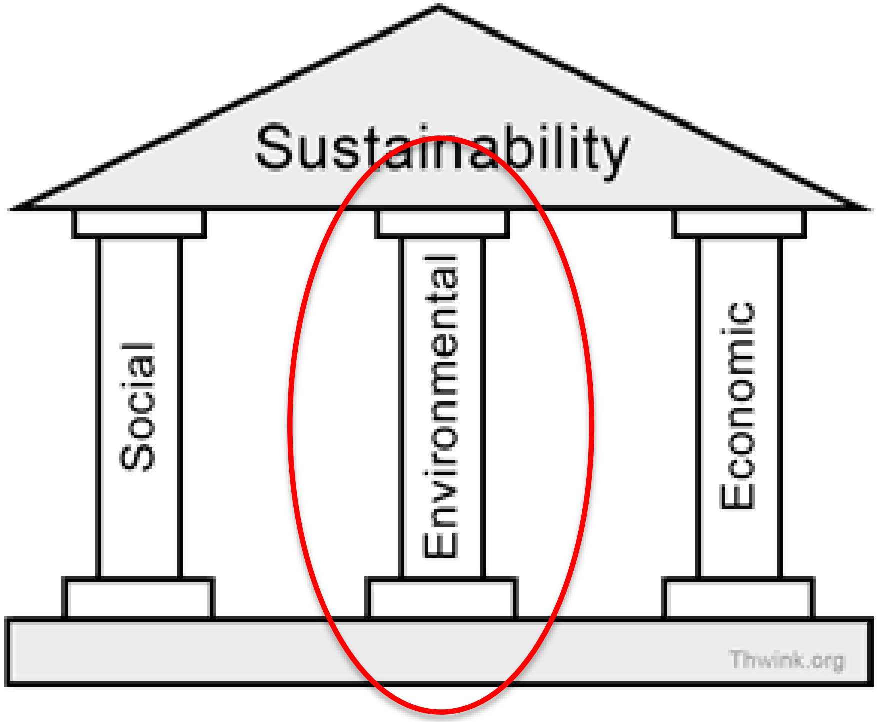
1.2 Three pillars model



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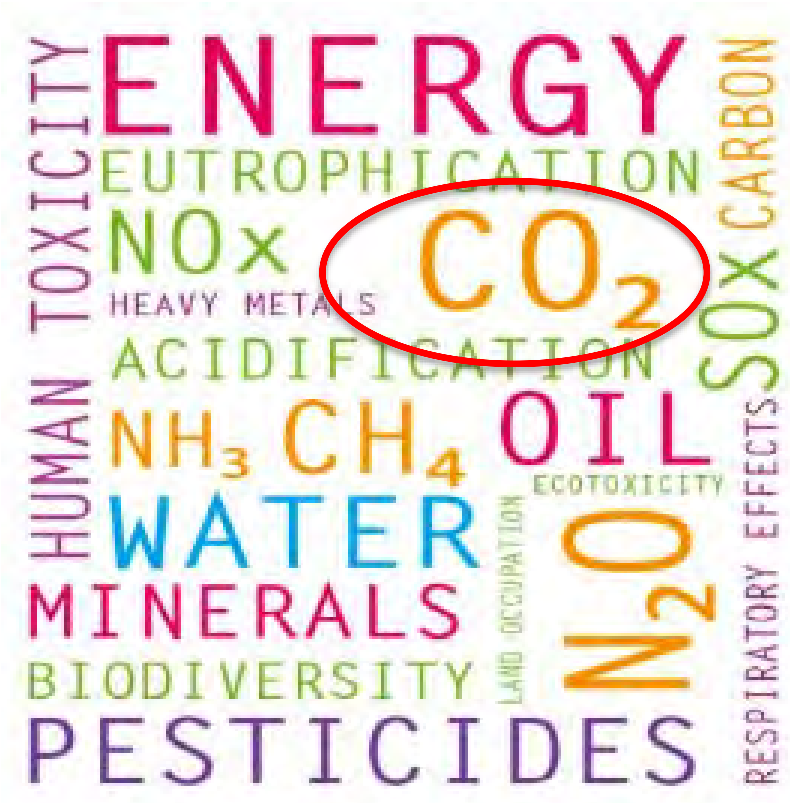
1.3 Lifecyle Assessment (LCA)

- **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

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2.1 Ecological footprint – a lifecycle analysis

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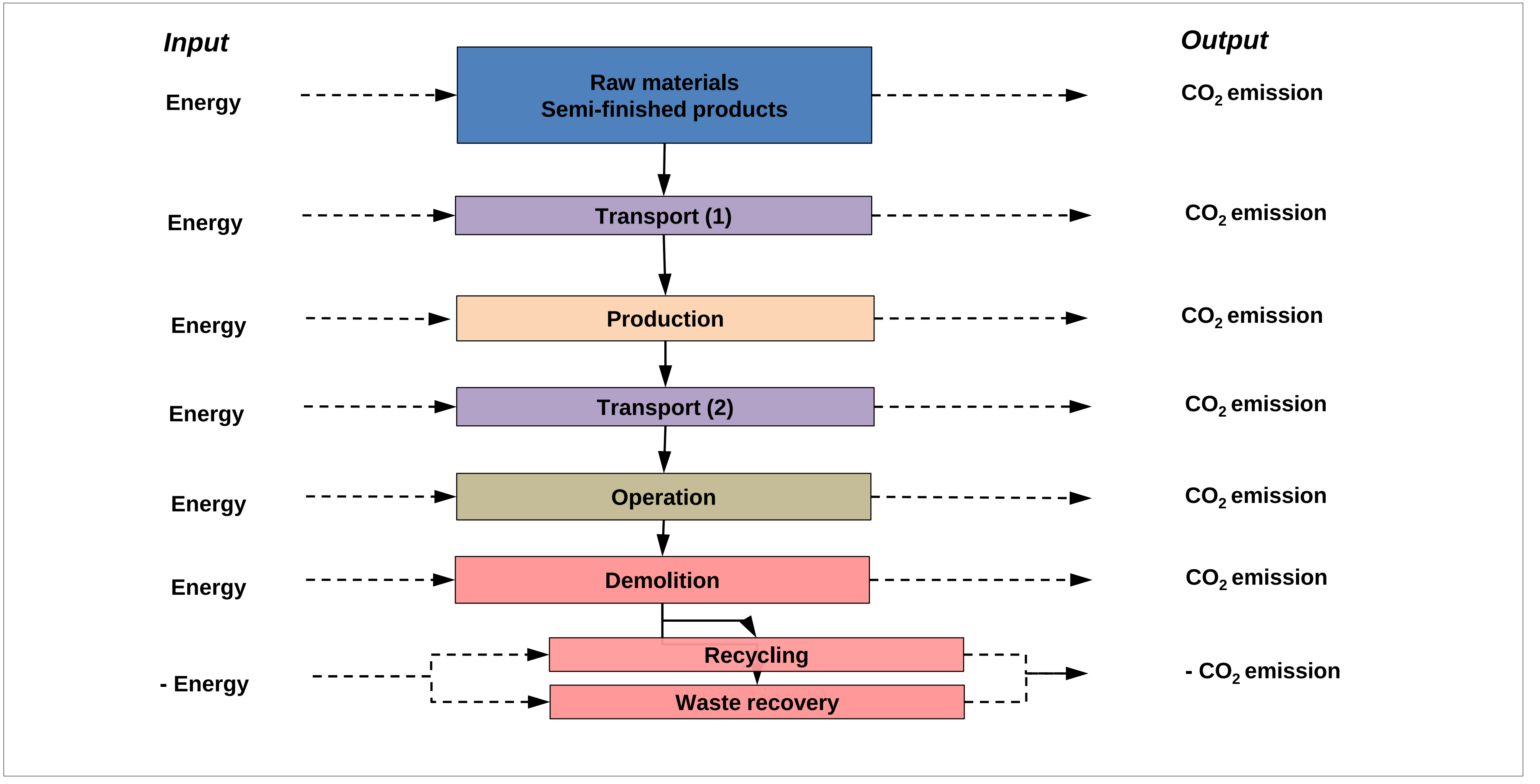
2.2 LCA – Set of unit processes within the product system



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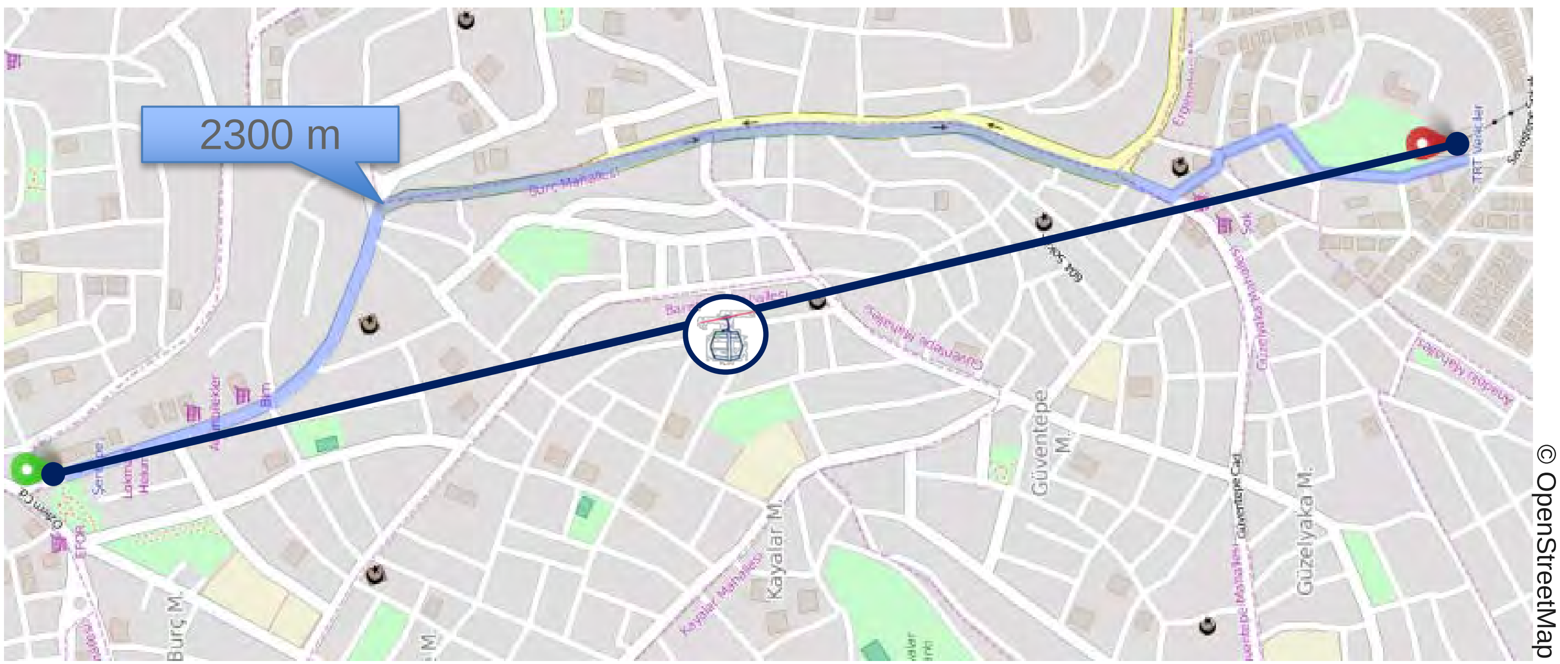
3.1 System description Ropeway GD10 Yenimahalle, Ankara (Turkey)



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

35 years

1881,7 m

75 m

2400 pphpd

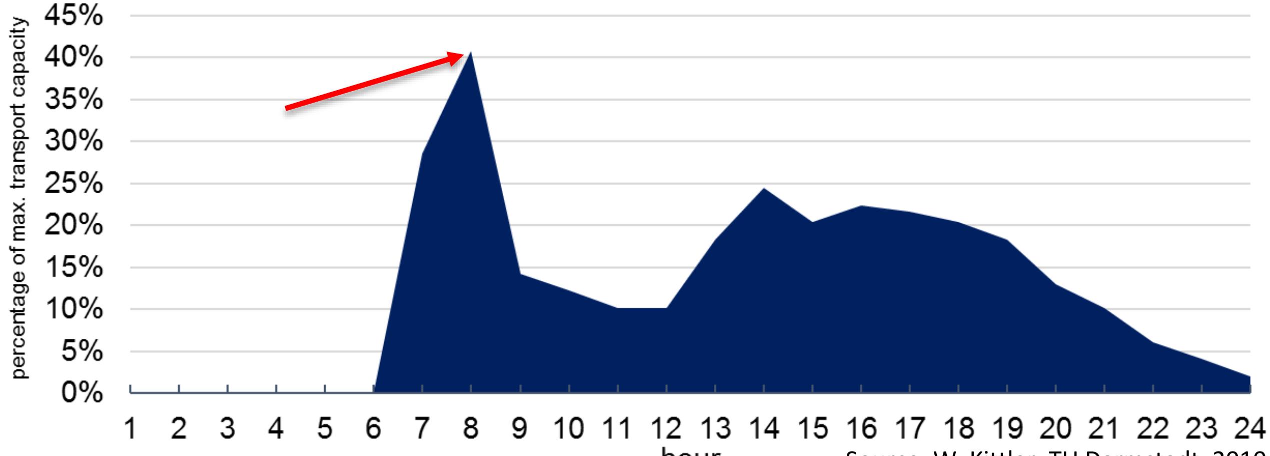
315 – 425 kW

88 p

9 p

Boarding area

Drive unit



Source: W. Kittler, TU Darmstadt, 2010

LEITNER ropeways

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 Feinblech (0,3-3,0mm)
Stahl Feinblech (20µm verzinkt)
→ Stahl warmgewalzte Bleche (2-20mm)
5 Beschichtungen
6 Kunststoffe
7 Komponenten von Fenstern und Vorhangfassaden
8 Gebäudetechnik
9 Sonstige

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4. Data sources and calculation model

4.1 Data sources

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

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4.2 Calculation model

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

Weight data from bill of material

	Stufe	Material	Kurzbezeichnung	[Gesamtgewicht] kg		Materialart	Wert	Einheit	INPUT
4									
5		A1	Rohstoffgewinnung und -verarbeitung und Verarbeitungsprozesse						PERT
6									
7	Stufe	Material	Kurzbezeichnung	[Gesamtgewicht] kg		Materialart	Wert	Einheit	INPUT
8									
9	1	84010396	TDS_RETUR_GD10 SOGN MARTIN-LA SIALA (CH)	127.735,08		95.167,72			PERT
10	2	84010588	TDS_R_GRO_GD10 SOGN MARTIN-LA SIALA (CH)	20.298,32		13.841,00			PERT
11	3	41009765-04	UMLENKGRUPPE-WEG 5M+1M 4900D 1000kN	16.254,64	kg	9.803,00			PERT
220	3	50102758-02	HI-SPANNEINR.US-5+1M-650KN H	4.043,69	kg	4.038,00			PERT
285	2	84010589	TDS_R_STR_GD10 SOGN MARTIN-LA SIALA (CH)	60.466,35		47.423,20			PERT
286	3	50220757-03	TRAGSTRUKTUR GD8 NO M. >4000	31.945,75	kg	25.513,00			PERT
350	3	50104267	Module vormontiert	7.422,79	kg	5.811,00			PERT
518	3	50100105	HOHE STRUKTUR LPA L=15.5m	8.247,14	kg	6.915,00			PERT
519	0	10000062	HEA-TRAEGER S355J0 HEA300	1.324,62	kg	Stahlprofil	1	kg	PERT
520	0	10000065	HEA-TRAEGER S355J0 HEA400	4.550,72	kg	Stahlprofil	1	kg	PERT
521	0	10000332	STAHLBLECH S275J0 15MM	10,81	kg	Stahl-Blech	1	kg	PERT
522	0	10000345	STAHLBLECH S355J2 20MM	31,95	kg	Stahl-Blech	1	kg	PERT
523	0	10000361	STAHLBLECH S355J2 30MM	622,95	kg	Stahl-Blech	1	kg	PERT
524	0	10000373	STAHLBLECH S355J2 35MM	50,43	kg	Stahl-Blech	1	kg	PERT
525	0	10001401	STAHLBLECH S355J2 15MM	1.229,52	kg	Stahl-Blech	1	kg	PERT
526	0	10100024	FEUERVERZINKUNG STANDARD	324,00	kg	kg-Verzinkung	1	kg	PERT
527	1	15101935	KLEBESCHILD CE - RICHTLINIE 20	0,00	kg	Normteil (g,v)	1	kg	PERT
528	1	20000110	SK-SCHRAUBE M30X120 8.8ISO4017	7,41	kg	Normteil (g,v)	1	kg	PERT
529	1	20002072	SK-MUTTER HV M30 10 EN 14399-4	19,92	kg	Normteil (g,v)	1	kg	PERT
530	1	20002075	BEILAGSCHEIBE 30 EN 14399-6	8,70	kg	Normteil (g,v)	1	kg	PERT
531	1	20005017	SK-MUTTER M30 8 ISO4032	3,94	kg	Normteil (g,v)	1	kg	PERT

Global Warming Potential:

$$GWP = material\ weight \cdot Factor\ GWPsteel\ sheet$$

Example

$$GWP = 42{,}76\ kg\ steel\ sheet \cdot 0{,}7509\ \frac{kgCO_2equivalent}{kg} = 32{,}11\ kg\ CO_2equivalent$$

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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)

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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	59,15m³	1	59,15 m³	PERT	1.266,80	12,52	- 773,88	505,44	kWh
2		Beton C30/37	9,6m³	1	9,60 m³	PERT	220,53	2,03	- 125,60	96,97	kWh
1	**77008158**	**Bewehrung Stationsfundament-Unterteil 1**	**8271 kg**	**1**	**8.271,00 kg**	**PERT**	**4.321,60**	**-**	**-**	**4.321,60**	**kWh**
2		Bewehrungsstahl D12	38kg	1	38,00 kg	PERT	19,86	-	-	19,86	kWh
2		Bewehrungsstahl D14	802kg	1	802,00 kg	PERT	419,05	-	-	419,05	kWh
2		Bewehrungsstahl D16	2868kg	1	2.868,00 kg	PERT	1.498,53	-	-	1.498,53	kWh
2		Bewehrungsstahl D20	3211kg	1	3.211,00 kg	PERT	1.677,75	-	-	1.677,75	kWh
2		Bewehrungsstahl D28	1352kg	1	1.352,00 kg	PERT	706,42	-	-	706,42	kWh
1	**77008159**	**Bewehrung Stationsfundament-Unterteil 2**	**1746 kg**	**1**	**1.746,00 kg**	**PERT**	**912,29**	**-**	**-**	**912,29**	**kWh**
2		Bewehrungsstahl D12	141kg	1	141,00 kg	PERT	73,67	-	-	73,67	kWh
2		Bewehrungsstahl D14	0kg	1	- kg	PERT	-	-	-	-	kWh
2		Bewehrungsstahl D16	331kg	1	331,00 kg	PERT	172,95	-	-	172,95	kWh
2		Bewehrungsstahl D20	78kg	1	78,00 kg	PERT	40,76	-	-	40,76	kWh
2		Bewehrungsstahl D28	1196kg	1	1.196,00 kg	PERT	624,91	-	-	624,91	kWh
1	**77008160**	**Bewehrung Stationsfundament-Oberteil**	**1610 kg**	**1**	**1.610,00 kg**	**PERT**	**841,23**	**-**	**-**	**841,23**	**kWh**
2		Bewehrungsstahl D12	195kg	1	195,00 kg	PERT	101,89	-	-	101,89	kWh
2		Bewehrungsstahl D14	362kg	1	362,00 kg	PERT	189,15	-	-	189,15	kWh
2		Bewehrungsstahl D16	111kg	1	111,00 kg	PERT	58,00	-	-	58,00	kWh
2		Bewehrungsstahl D20	333kg	1	333,00 kg	PERT	173,99	-	-	173,99	kWh
2		Bewehrungsstahl D28	609kg	1	609,00 kg	PERT	318,20	-	-	318,20	kWh

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

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4.2 Calculation model – operation of the ropeway

Time of day		Monday - Friday	Diurnal vaiation	Diurnal variation	Nr. of passengers	Utilization factor	Energy consumption
from	to	operation	characteristics	daily share	in both directions		[kWh]
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%	9,59%	1.370	29%	346,4
7	8	1	100%	13,70%	1.957	41%	359,8
8	9	1	35%	4,79%	685	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**

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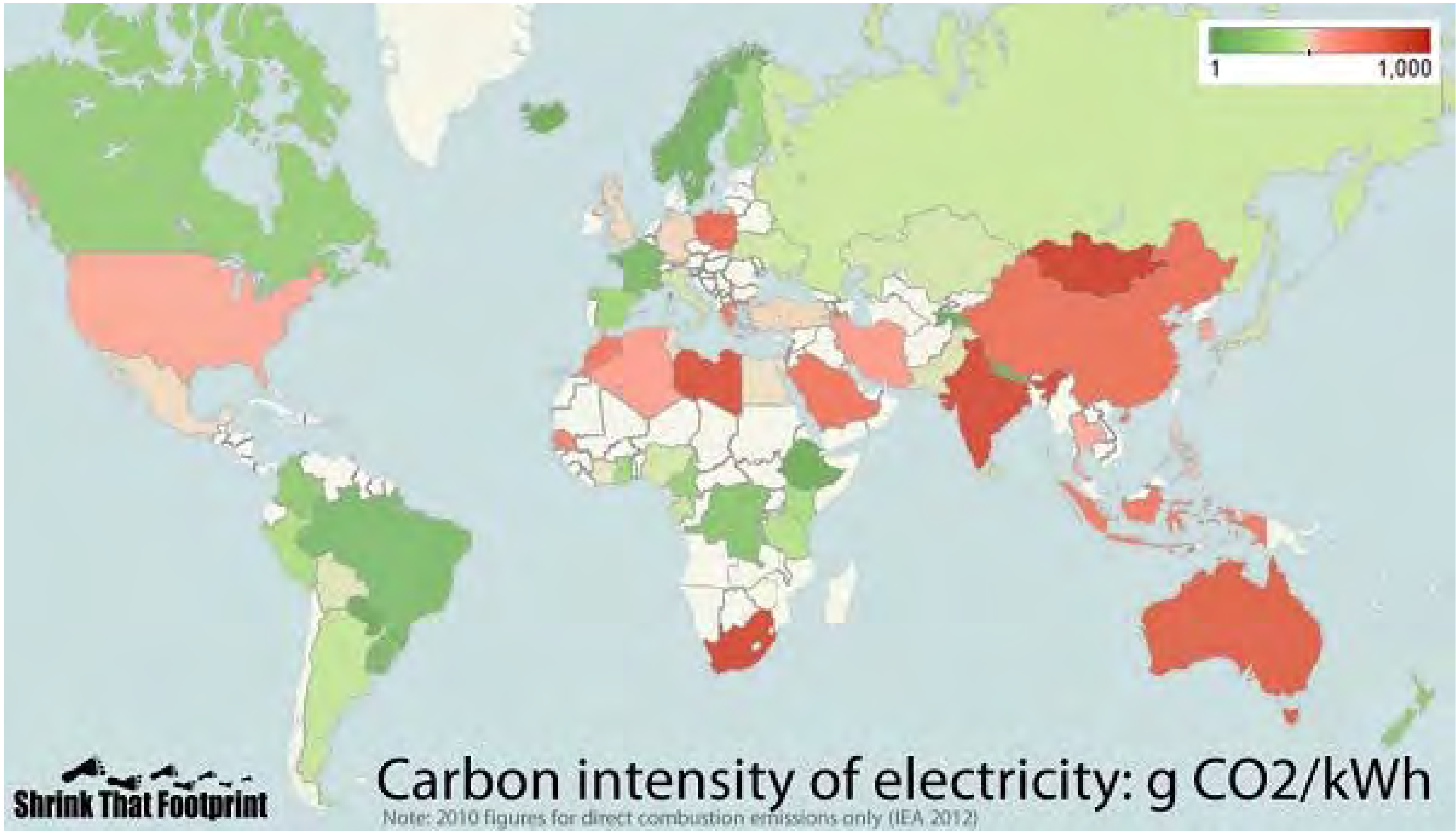
4.2 Calculation model – energy mix



Source: greenbiz.it

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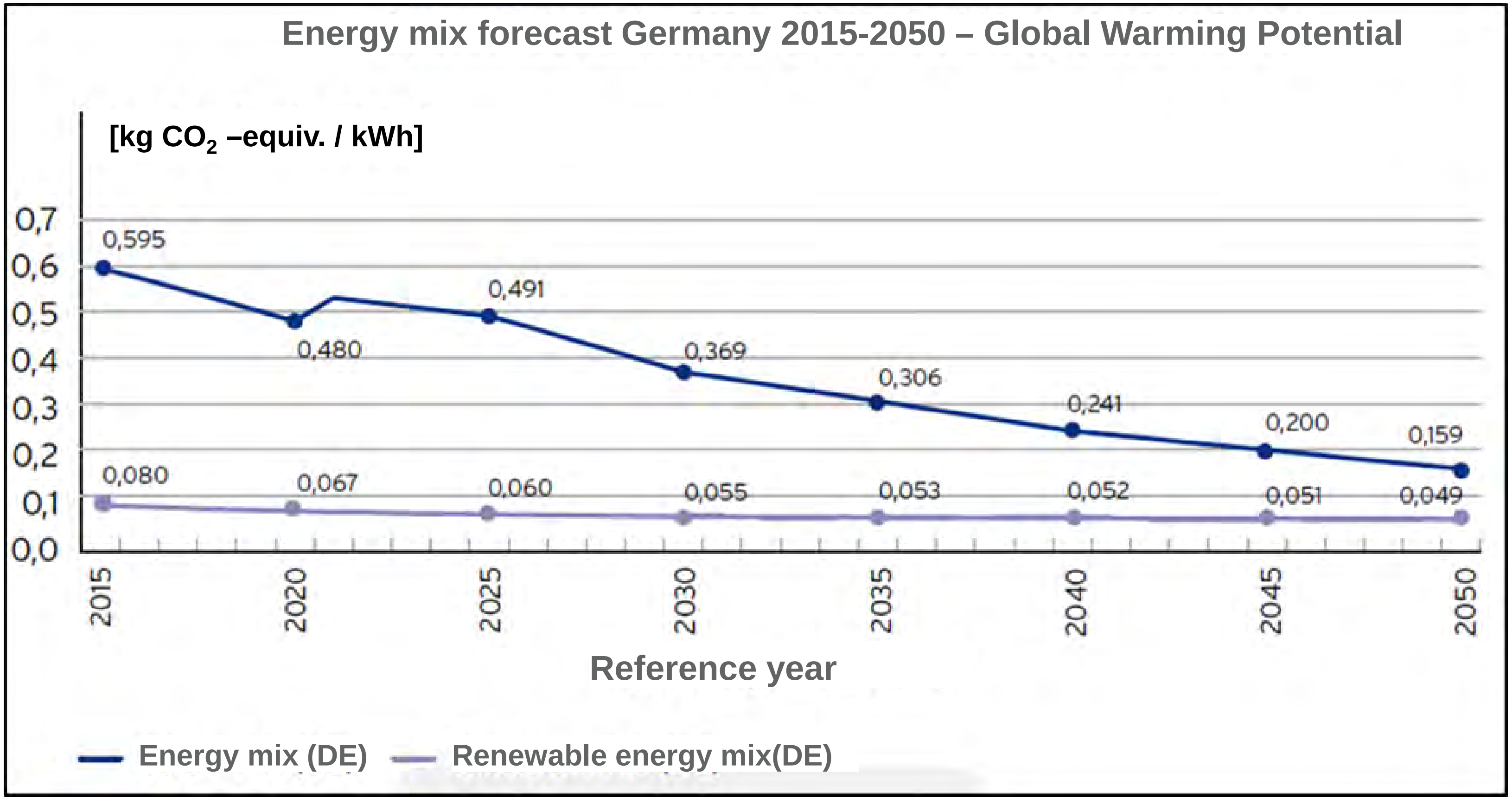
4.2 Calculation model – energy mix forecast Germany



Source: BM für Verkehr und digitale Infrastruktur, 2016

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4.2 Calculation model – operation of the ropeway

d) Operation of the ropeway

Calculation Global warming potential (year 2015)

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

Example

$$GWP = 2.100.467\,\frac{kWh}{y} \cdot 0{,}549\,\frac{kgCO_2equivalent}{kg} = 1{,}153\,\frac{Mio.\,kgCO_2equivalent}{y}$$

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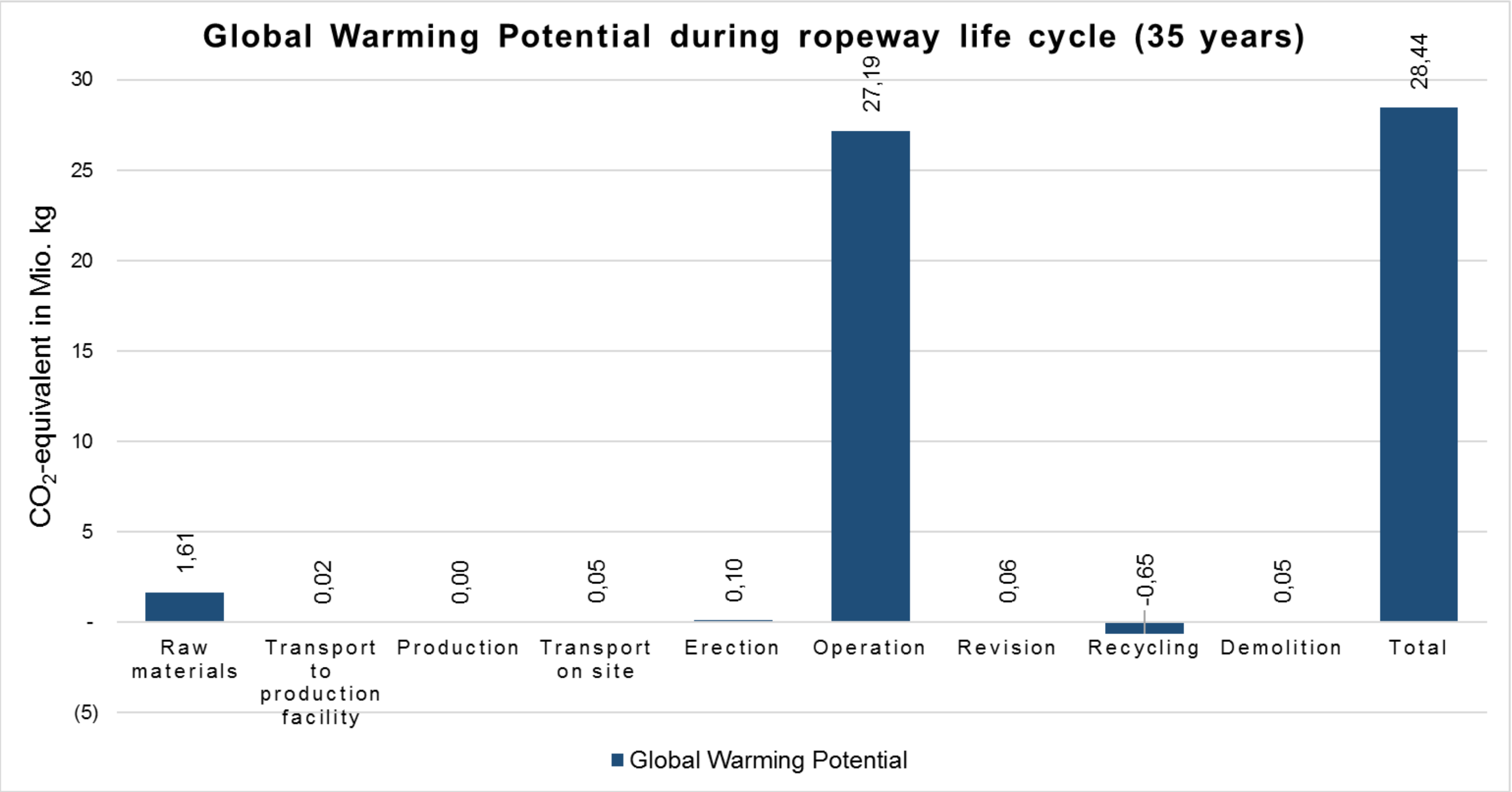
4.3 Results



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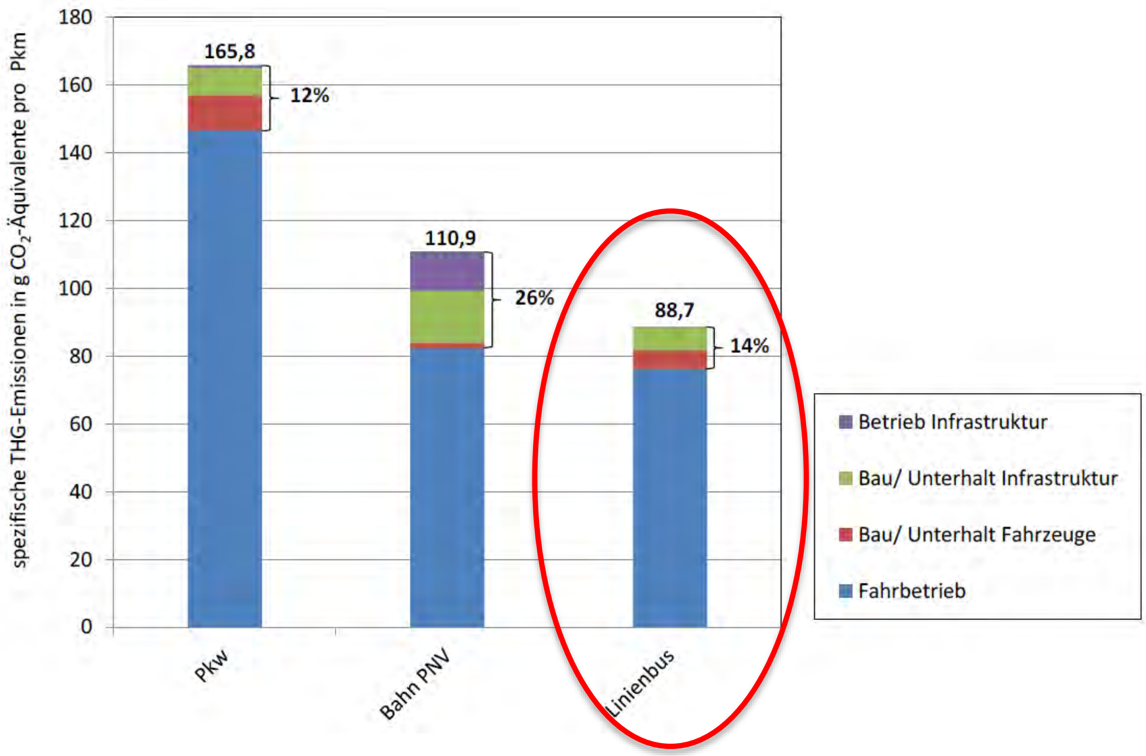
5.1 Diesel Bus system

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



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

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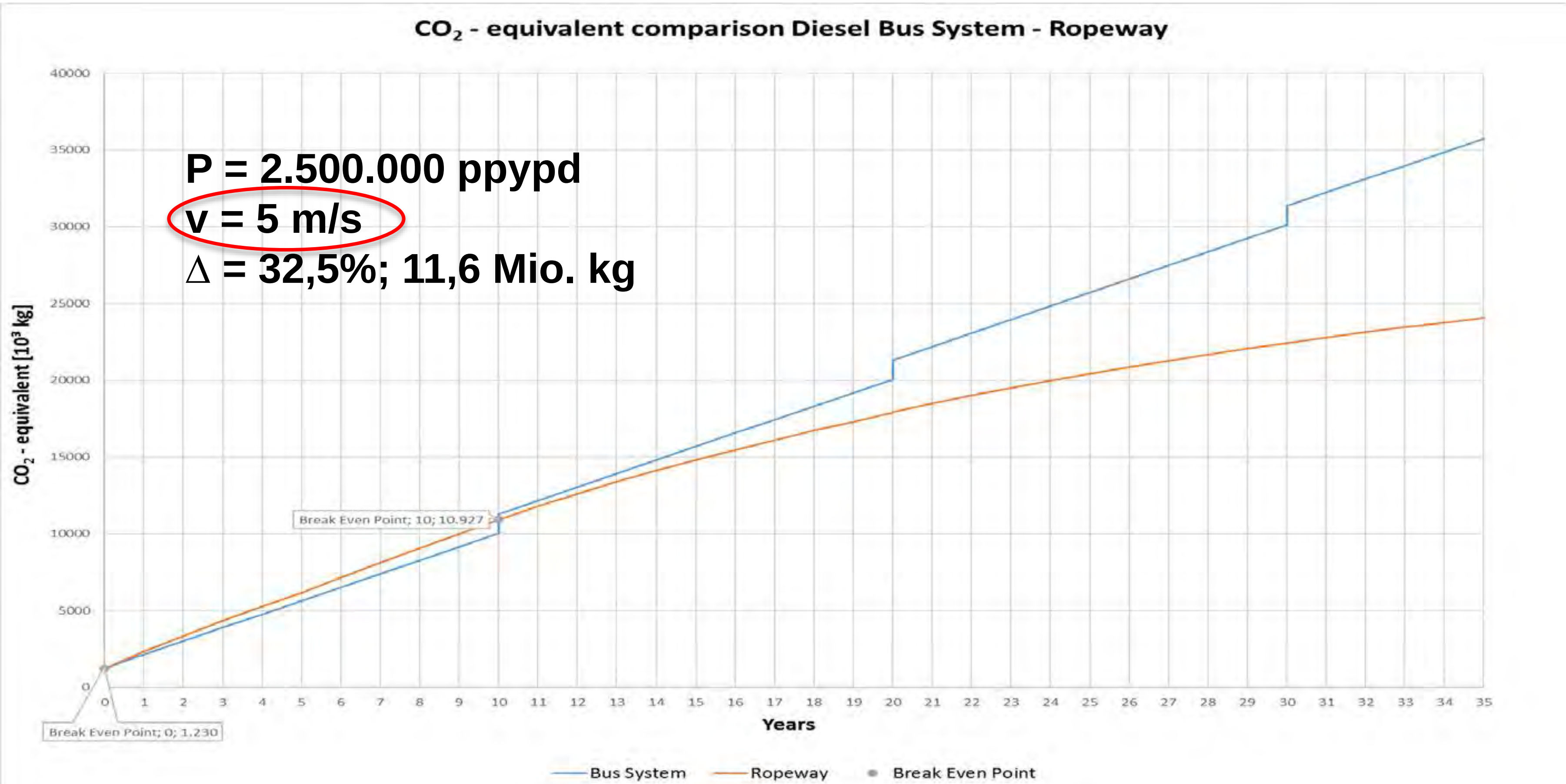
5.2 Example Yenimahalle – energy mix forecast DE



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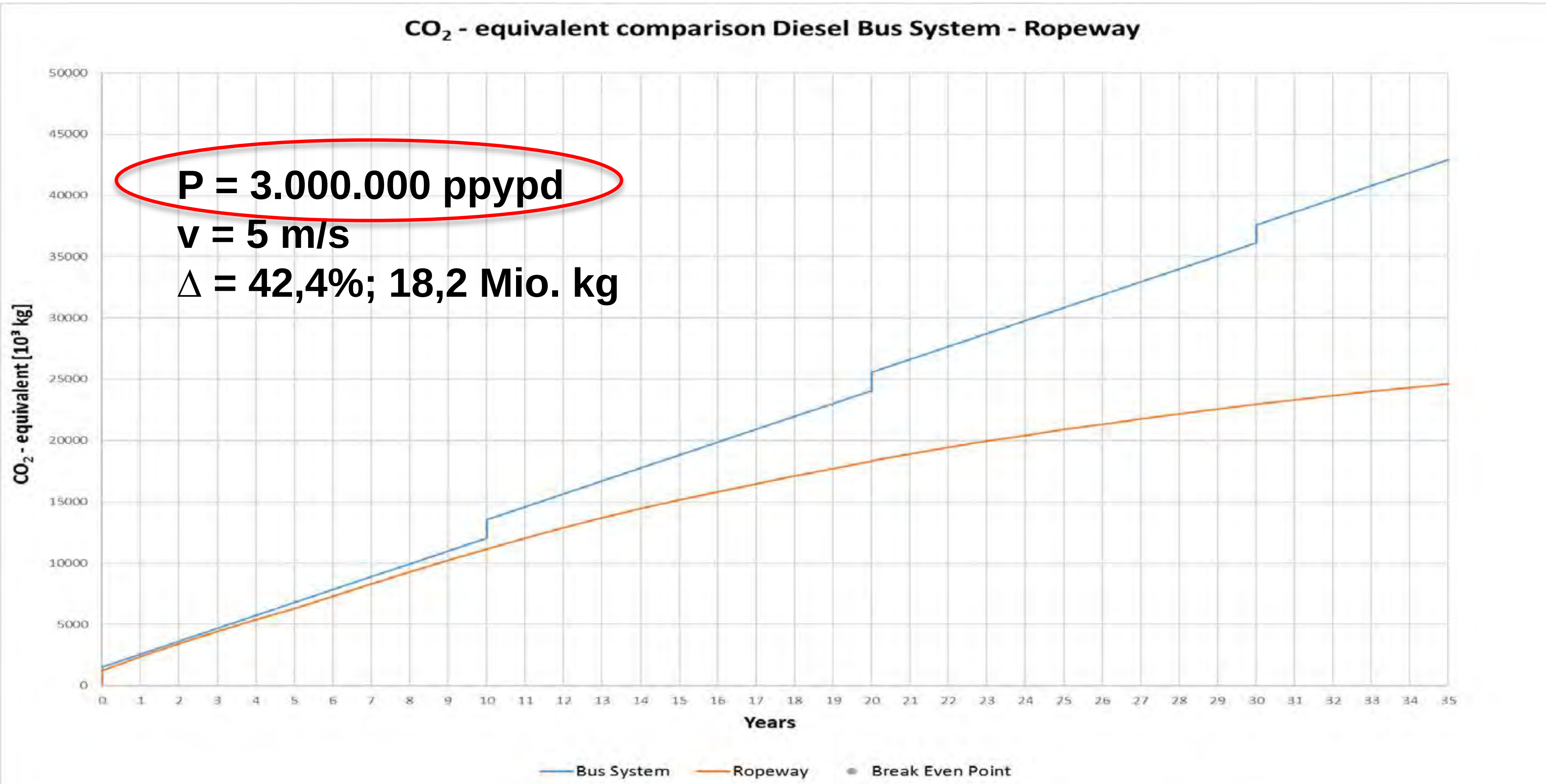
5. System comparison

5.3 Example Yenimahalle – energy mix forecast DE



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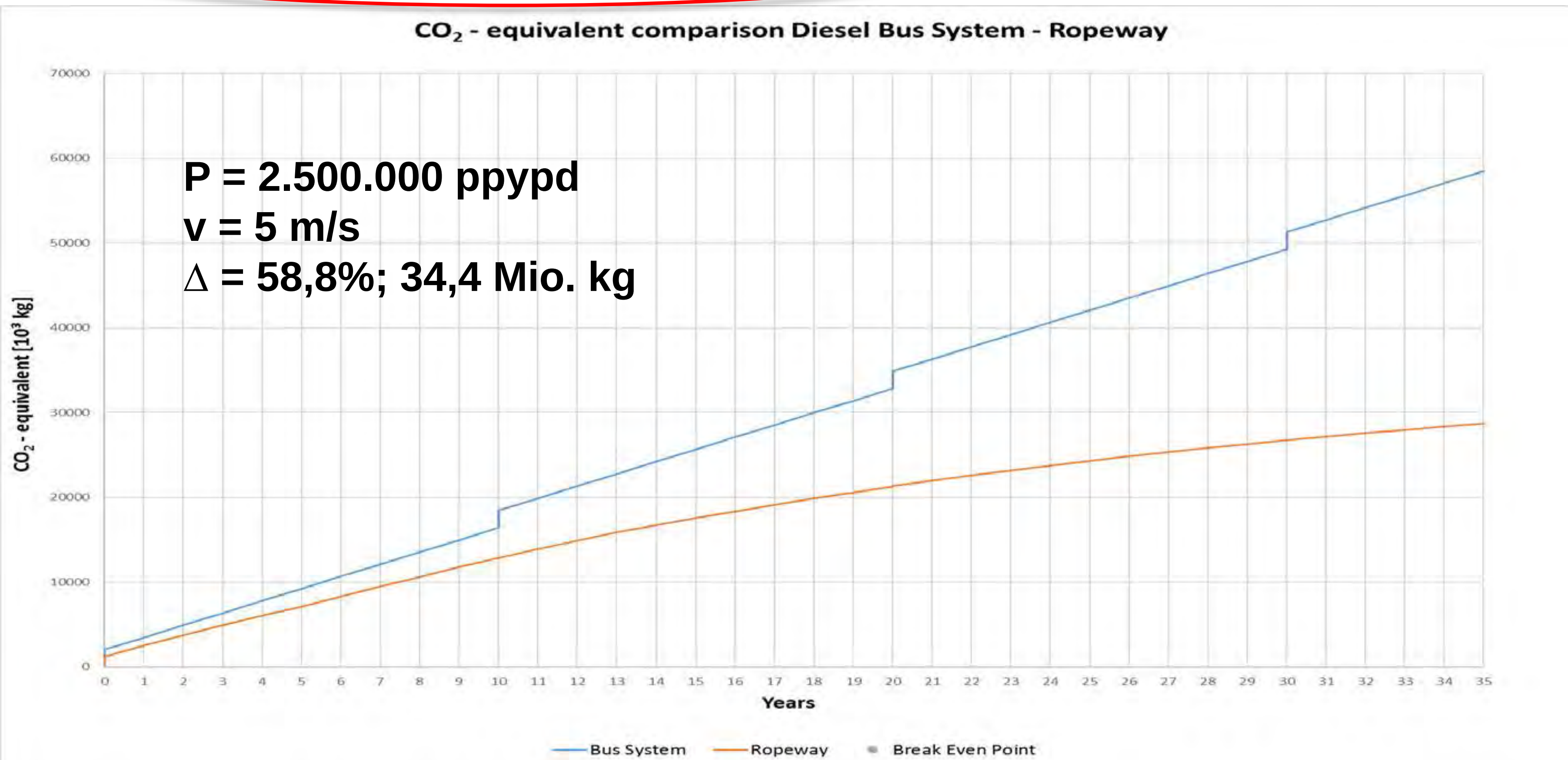
5.4 Example Yenimahalle – energy mix forecast DE (length Bus line = 2x length Ropeway line)



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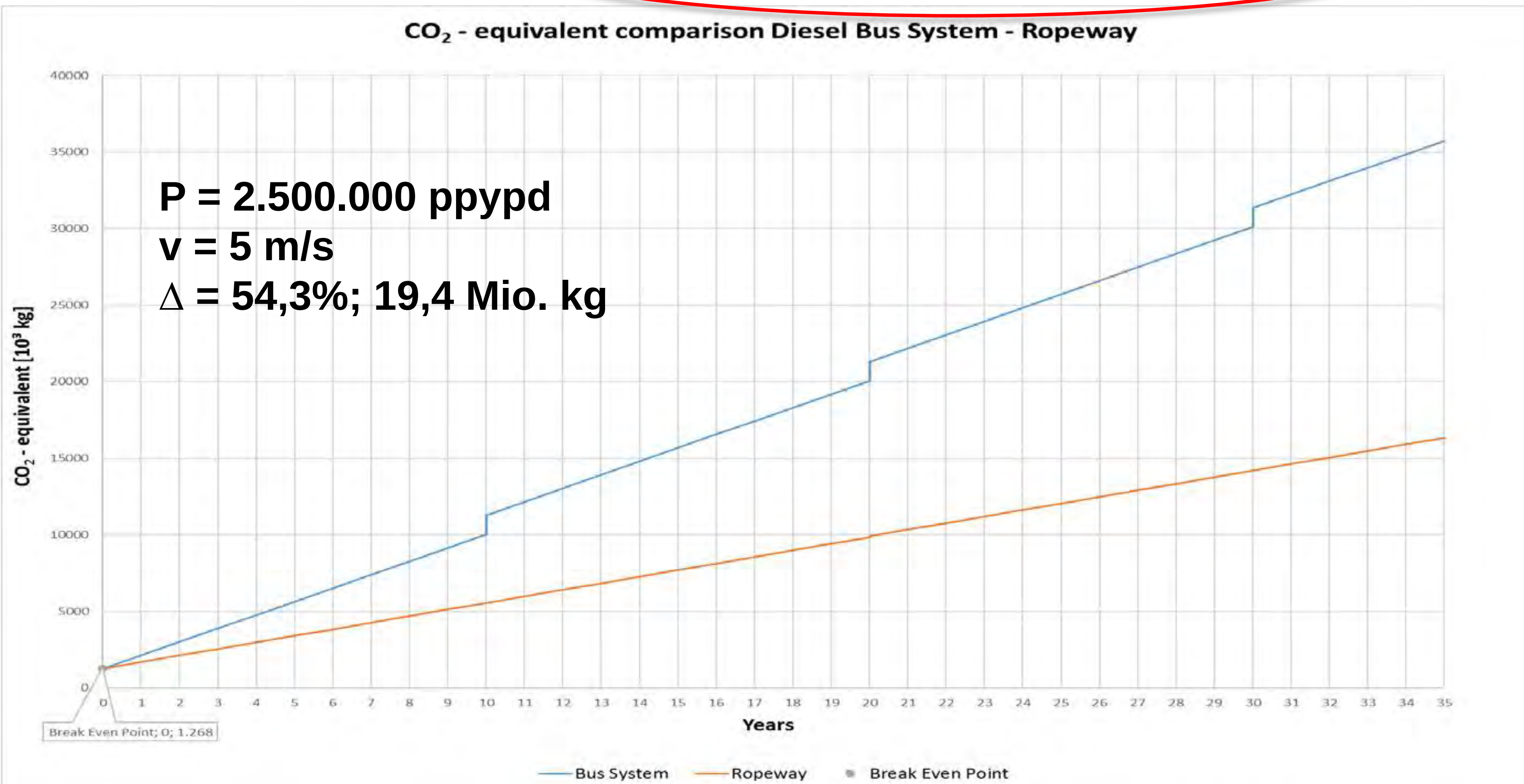
5.5 Example Yenimahalle – energy mix Austria 2015 (0,231 kg CO_2/kWh)



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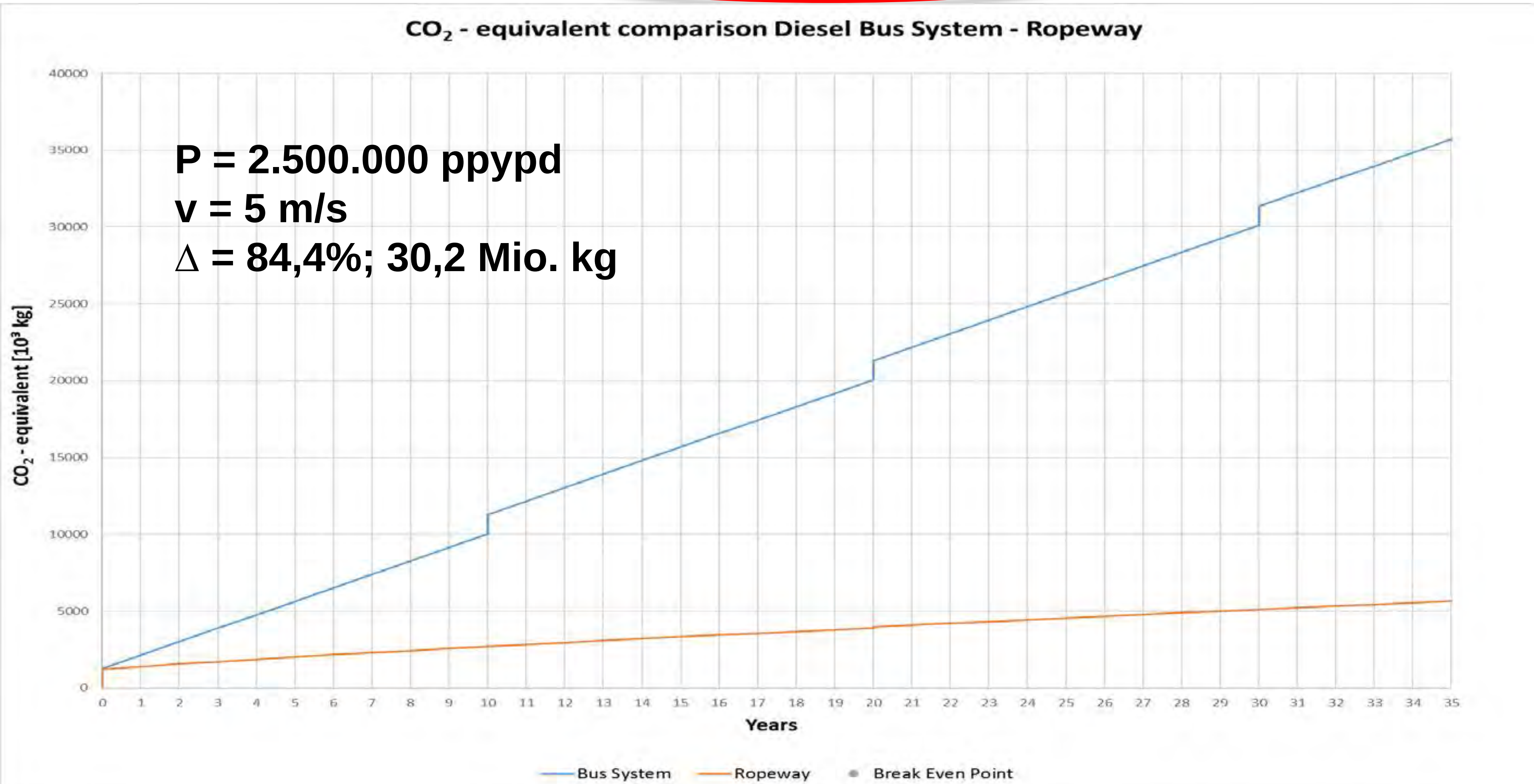
5.6 Example Yenimahalle – green electricity forecast DE



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5.7 Future scenario „pure electromobility“:

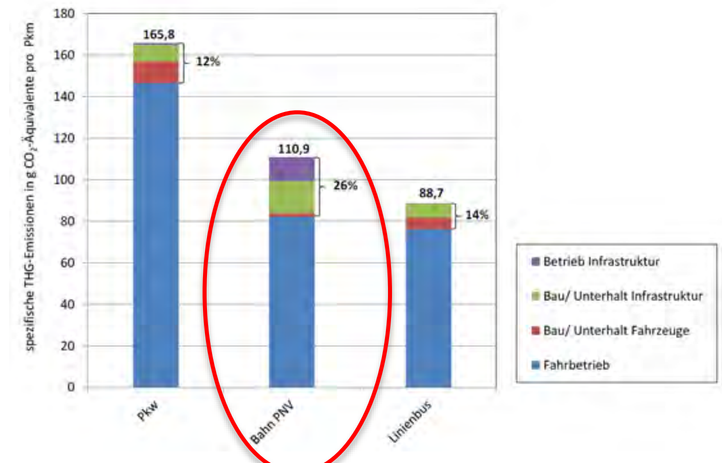
- **Electromobility by battery powered busses**
- **Power generation by green electricity**

Hypothesis: reduction CO_2 emissions bus proportional to energy production ratio

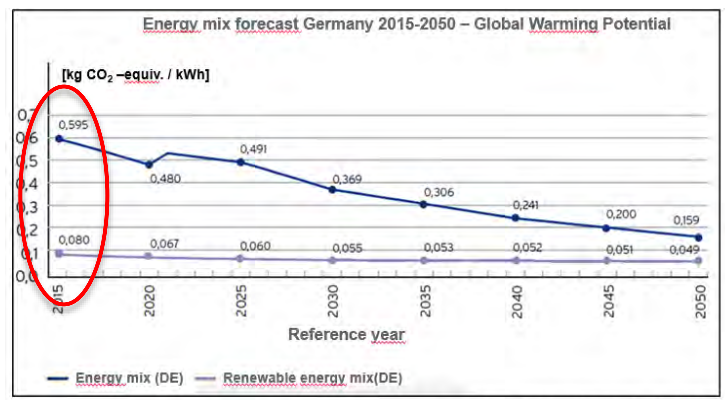
Electric tram (today) = 81 g CO_2 / km p

Electric Bus (tomorrow) = 81 * (0,080/0,595)
= 10,9 g CO_2 / km p

⇨ Reduction CO_2 emissions of 86,5%



Source: Umweltbundesamt, Texte Nr. 96/2013



Source: BM für Verkehr und digitale Infrastruktur, 2016

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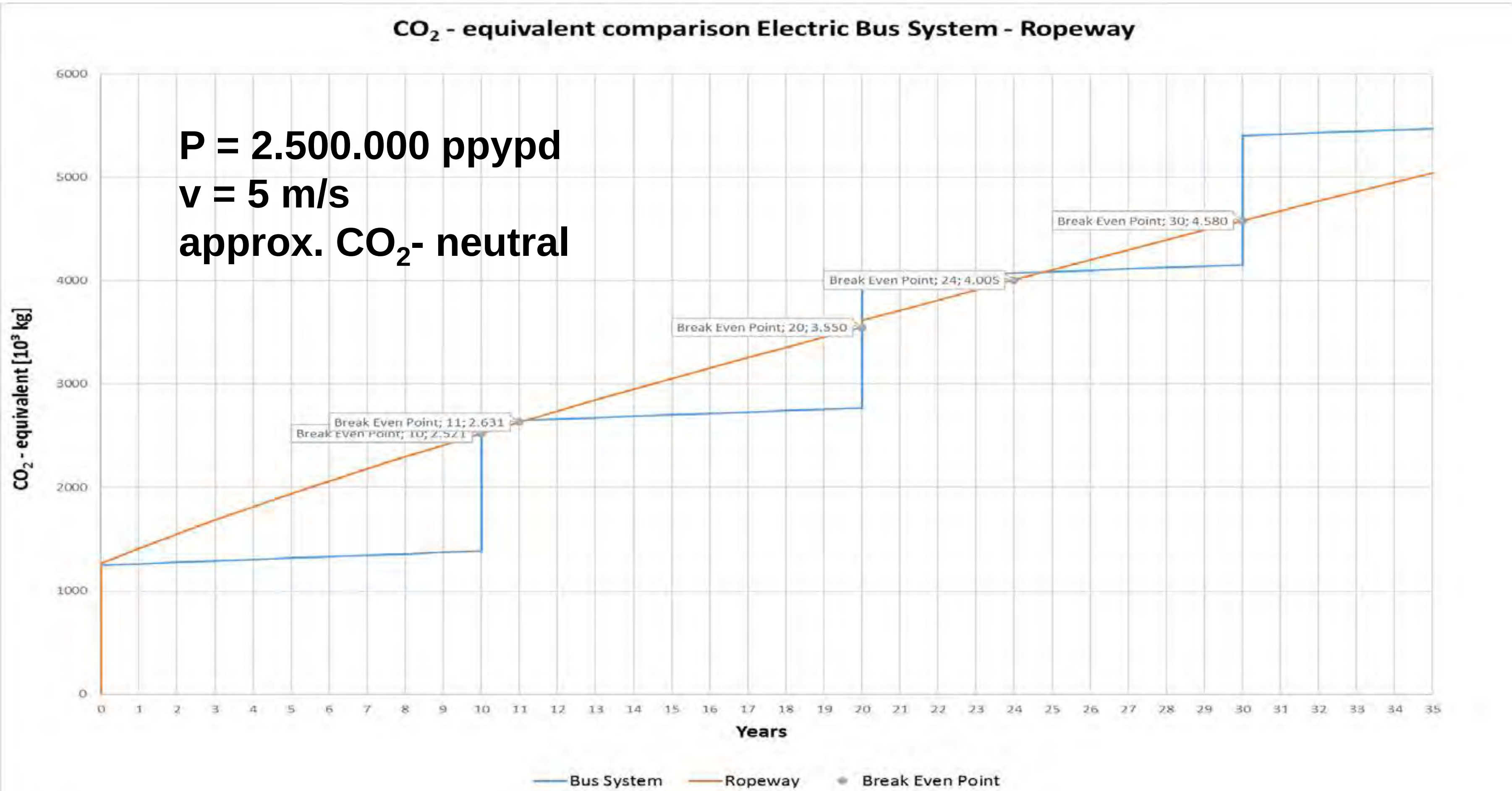
Example Yenimahalle – pure electromobility



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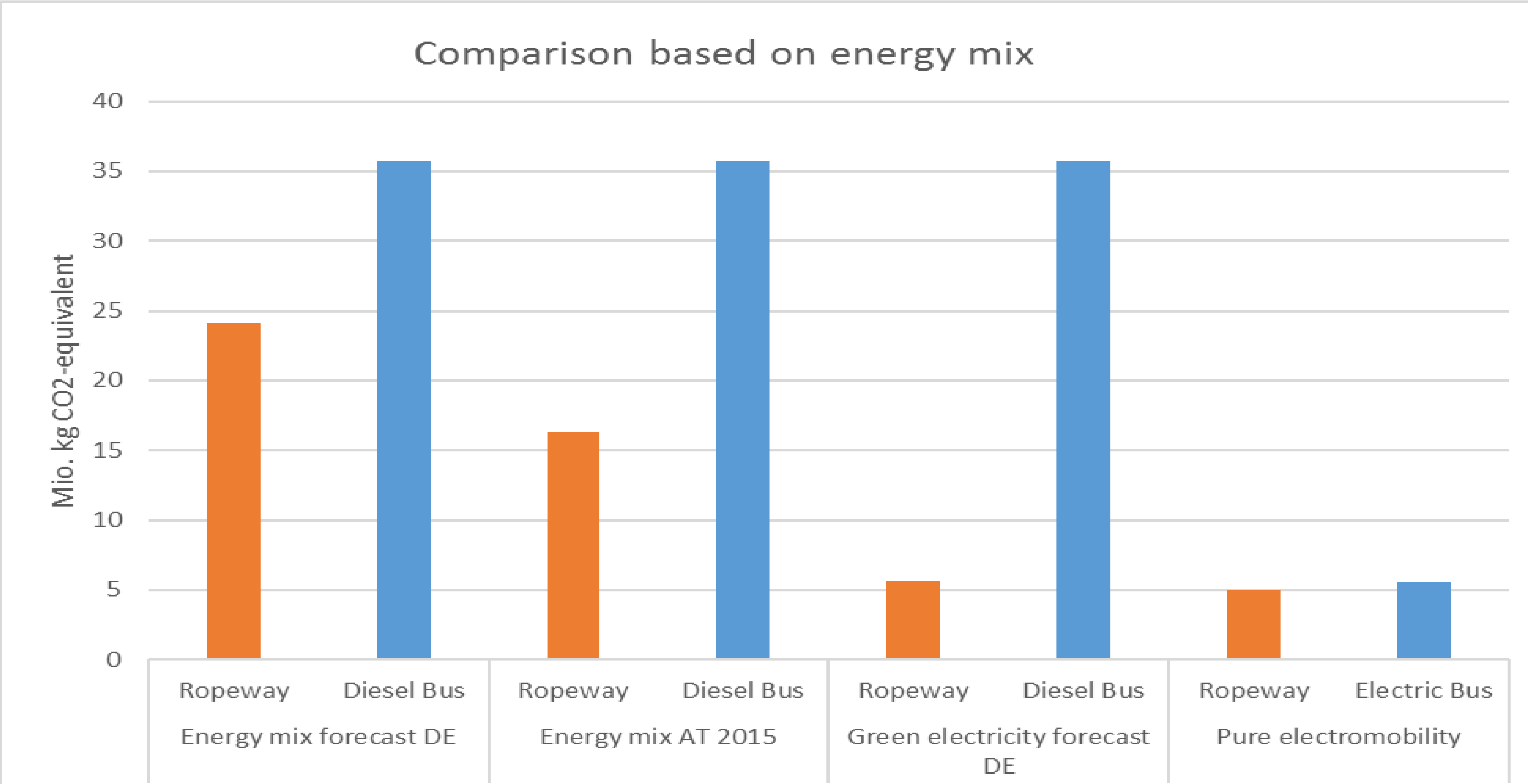
5.9 General considerations



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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

GD10 Cambulos – Villamaria, Manizales / CO 2013

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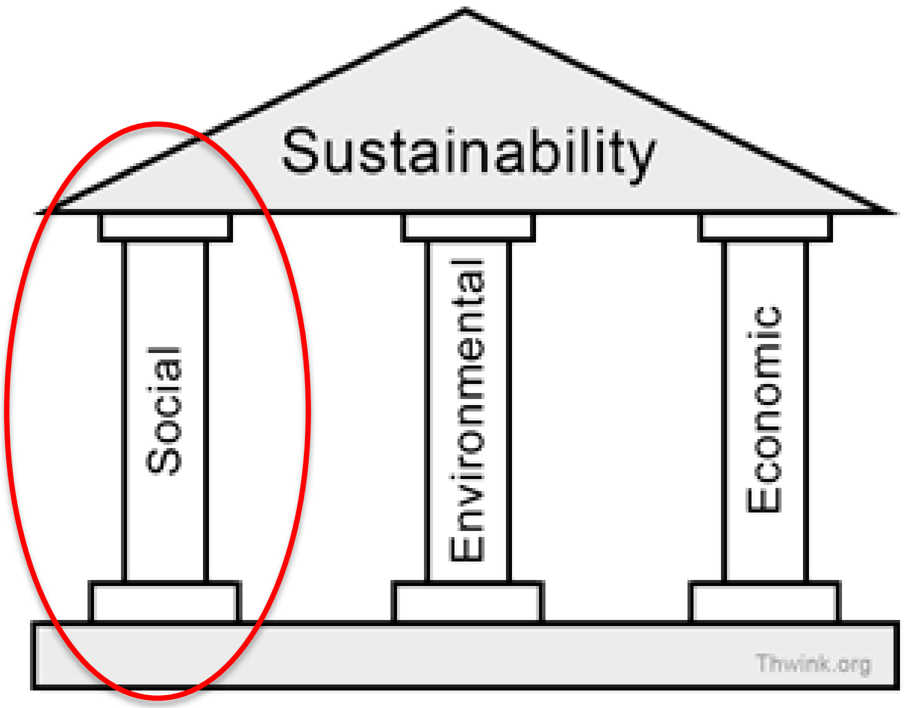
6.2 Sustainability – social development



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6.2 Sustainability – social development

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