EuP Lot 30:
Electric Motors and Drives

Task 5: Definition of Base Case

ENER/C3/413-2010

Final

June 2014

Anibal De Almeida

Hugh Falkner

João Fong

Contents

5 Definition of Base Case 4
5.1 Introduction 4
5.2 Overview of Methodology 5
5.1.1 Subtask 5.1 Product-specific Inputs 5
5.1.2 Sub-task 5.2 Base-Case Environmental Impact Assessment 5
5.1.3 Subtask 5.3 Base-Case Life Cycle Costs 5
5.1.4 Sub-task 5.4 EU Totals 5
5.1.5 Sub-task 5.5 EU-27 Total System Impact 5
5.3 MEEUP Model Input data 6
5.1.6 Motor and VSD time : load data 6
5.1.7 Motor and VSD MEEUP Input Data 6
5.1.8 Soft Starter MEEUP Input Data 8
5.1.9 Submersible borehole pump motor 9
5.1.10 Motor + VSD 9
5.1.11 Overview 9
5.1.12 Soft starters 10
5.1.13 Induction motors 10
5.1.14 Variable Speed Drives 11
5.1.15 Multistage submersible borehole pump motors 11
5.1.16 Combined Motor + controller 11
5.2 Summary of lifetime environmental impacts, by basecase 13
5.2.1 Basecase 1 Small Induction Motor – I phase IE1 0.37kW 13
5.2.2 Basecase 2 Small induction motor – 3 phase IE1 0.37kW 14
5.2.3 Basecase 3 Medium induction motor (S) - 3 phase IE2 1.1kW 15
5.2.4 Basecase 4 Medium induction motor (M) - 3 phase IE2 11kW 16
5.2.5 Basecase 5 Medium induction motor (L) - 3 phase IE2 110kW 17
5.2.6 Basecase 6 Large induction motor – LV IE2 550kW 18
5.2.7 Basecase 7 Large induction motor – MV IE2 550kW 19
5.2.8 Basecase 8 VSD Very small 0.37kW 20
5.2.9 Basecase 9 VSD Small 1.1kW 21
5.2.10 Basecase 10 VSD Medium 11kW 22
5.2.11 Basecase 11 VSD Large 110kW 23
5.2.12 Basecase 12 VSD Very Large 550kW 24

5.2.13 Basecase 13 Soft Starter Small 1.1kW 25
5.2.14 Basecase 14 Soft Starter, Medium 11kW 26
5.2.15 Basecase 15 Soft Starter Large 110kW 27
5.2.16 Basecase 16 Submersible borehole pump motor Small 2.2kW 28
5.2.17 Basecase 17 Submersible borehole pump motor Large 37kW 29
5.2.18 Basecase 18 Motor + VSD Very Small 0.37kW 30
5.2.19 Basecase 19 Motor + VSD Small 1.1kW 31
5.2.20 Basecase 20 Motor + VSD Medium 11kW 32
5.2.21 Basecase 21 Motor + VSD Large 110kW 33
5.2.22 Basecase 22 Motor + VSD Very Large 550kW 34
5.3 Conclusions 35

5 Definition of Base Case

5.1 Introduction

A total of 22 basecases have been selected to ensure that the key characteristics of each group of products are adequately captured. If differences between basecases are found to be negligible, then it is possible that at a later stage some basecases might be merged.

The basecase models are based closely on real products, but care must be taken in interpretation of the whole stock results, as it cannot be certain that the basecases selected are a statistical average of the range they are representing.

Basecase Descriptions

Basecase 1: Small induction motor - 1 phase IE1 0.37kW

Basecase 2: Small induction motor - 3 phase IE1 0.37kW

Basecase 3: Medium induction motor (S) - 3 phase IE2 1.1kW

Basecase 4: Medium induction motor (M) - 3 phase IE2 11kW

Basecase 5: Medium induction motor (L) - 3 phase IE2 110kW

Basecase 6: Large induction motor - LV IE2 550kW

Basecase 7: Large induction motor - MV IE2 550kW

Basecase 8: VSD - Very Small 0.37kW

Basecase 9: VSD - Small 1.1kW

Basecase 10: VSD - Medium 11kW

Basecase 11: VSD - Large 110kW

Basecase 12: VSD - Very Large 550kW

Basecase 13: Soft Starter - Small 1.1kW

Basecase 14: Soft Starter - Medium 11kW

Basecase 15: Soft Starter - Large 110kW

Basecase 16: Submersible borehole motor - Small 2.2kW*

Basecase 17: Submersible borehole motor - Large 37kW*[1]

[1] Submersible Motors are a separable part of the Multistage submersible borehole pumps considered in Lot29. The analysis of these is within LOT30 so that the analysis is done on the same basis as other motors, but the results of this analysis will be highly relevant to LOT29.

Basecase 18: Motor + VSD - Very Small 0.37kW

Basecase 19: Motor + VSD - Small 1.1kW

Basecase 20: Motor + VSD - Medium 11kW

Basecase 21: Motor + VSD - Large 110kW

Basecase 22: Motor + VSD - Very Large 550kW

It is noted that MV VSDs will have a lifetime of 21 years, compared to the assumed LV VSD basecase lifetime of 17 years. This variation is considered to be within the boundaries of the LV basecase, and the impact of this can be explored in more detail if subsequent analysis shows that measures applicable to Large VSDs are recommended.

5.2 Overview of Methodology

5.1.1 Subtask 5.1 Product-specific Inputs

This section uses information from Task 4 to create specific values relating to stock, energy use, bill of materials, and other costs of ownership, which are shown in section 5.3.

5.1.2 Sub-task 5.2 Base-Case Environmental Impact Assessment

This uses the VHK ecodesign model to determine the environmental emissions from each product over each phase of its life

- Raw Materials Use and Manufacturing;
- Distribution;
- Use;
- And End-of-Life Phase.

5.1.3 Subtask 5.3 Base-Case Life Cycle Costs

This stage calculates the total environmental impact over the life cycle of each basecase.

5.1.4 Sub-task 5.4 EU Totals

This stage totals the environmental impact of the stock of products sold in one year.

5.1.5 Sub-task 5.5 EU-27 Total System Impact

This stage gives the total EU impact of the stock of products over their lifetime.

The results of Task 5 will highlight which parameters are important, with important parameters at a later stage being subjected to sensitivity analysis and / or the collection of more refined data. For clarity, the detailed outputs of the model are included as Annex 1.

Note that for clarity, the Motor and VSD basecases include those products used in the combined Motor + VSD basecases. Care must be taken to avoid double counting of both energy use and energy savings potential.

5.3 MEEUP Model Input data

5.1.6 Motor and VSD time : load data

Product	100%	75%	50%	25%
Motor	0.2	0.3	0.3	0.2
VSD	0.25	0.5	0.2	0.05

Figure 5.1: Time:Load duraction values for Motors and VSDs

The selection of 25, 20, 75 and 100% load points is in line with published motor data. However, for the purposes of this study, note that these load points are best considered as the mid-point of a load range, ie87.5% - 112.% etc, not everything between the load point and next lowest load point (which would have been 75% – 100% etc). This approach does cause a small anomaly at very low loads, the impact of which will need reviewing to check it does not lead to misleading results.

5.1.7 Motor and VSD MEEUP Input Data

Figure 5.2 shows the assumed efficiencies and annual running hours used in the basecase models, Figure 5.3 other lifetime cost information, and Figure 5.4 the Bill of Materials for each.

Basecase Ref	Description	Power Range corresponding to basecase	Basecase Size (kW)	Efficiency (%) at load points				Running Hours pa
				100%	75%	50%	25%	
1	Small induction motor - 1 phase IE1	0.15 - 0.75 kW	0,37	66	71	70	61	400
2	Small induction motor - 3 phase IE1	0.15 - 0.75 kW	0,37	66	71	70	61	2000
3	Medium induction motor (S) - 3 phase IE2	0.75 - 7.5 kW	1,1	81,4	82	80	72	2250
4	Medium induction motor (M) - 3 phase IE2	7.5 - 75kW	11	89,8	90	89	85	3000
5	Medium induction motor (L) - 3 phase IE2	75 - 375kW	110	94,5	94,5	94	92,5	6000
6	Large induction motor - LV IE2	375 - 1,000kW	550	95,1	95,1	95,1	94	6000
7	Large induction motor - MV IE2	375 - 1,000kW	550	96,6	96,6	96,6	95,5	6000
8	VSD - Very Small	0.15 - 0.75 kW	0,37	85,6	81,6	76,0	62,5	2000
9	VSD - Small	0.15 - 7.5kW	1,1	91,3	88,7	85,6	77,3	2250
10	VSD - Medium	7.5 - 75kW	11	94,8	93,2	92,2	89,7	3000
11	VSD - Large	75 - 375kW	110	96,0	94,8	94,5	93,7	6000
12	VSD - Very Large	375 - 750kW	550	96,1	94,8	94,6	94,0	6000

Figure 5.2: Motor and VSD energy use input

Basecase Ref	Description	Power Range corresponding to	Basecase Size (kW)	Costs (euros)			Repair Distance (km)	EU Sales Mln pa	Lifetime (Years)	Stock Units (Mln)	Total Energy Losses of Stock (TWhpa)
				Installation	Repair	Unit					
1	Small induction motor - 1 phase IE1	0.12 - 0.75 kW	0.37	20	0	60	0	90	9	810	34.9
2	Small induction motor - 3 phase IE1	0.12 - 0.75 kW	0.37	20	0	200	0	11.7	9	105	22.7
3	Medium induction motor (S) - 3 phase IE2	0.75 - 7.5 kW	1.1	40	0	150	0	6.66	11	73	27.6
4	Medium induction motor (M) - 3 phase IE2	7.5 - 75kW	11	80	700	600	75	1.34	11	15	36.5
5	Medium induction motor (L) - 3 phase IE2	75 - 375kW	110	250	6,000	6,000	200	0.1	17	2	43.0
6	Large induction motor - LV IE2	375 - 1,000kW	550	1,500	20,000	25,000	200	0.01	17	0.17	18.4
7	Large induction motor - MV IE2	375 - 1,000kW	550	2,000	25,000	35,000	200	0.003	21	0.06	4.7
8	VSD - Very Small	0.12 - 0.75 kW	0.37	200	0	200	0	5	9	45	7.5
9	VSD - Small	0.75 - 7.5kW	1.1	280	0	280	0	2.6	9	23.4	6.2
10	VSD - Medium	7.5 - 75kW	11	1,130	200	1,130	75	0.2	11	2.2	3.2
11	VSD - Large	75 - 375kW	110	5,320	1,200	5,320	100	0.01	11	0.11	2.2
12	VSD - Very Large	375 - 750kW	550	41,790	1,200	41,790	100	0.007	17	0.119	11.7
16	Submersible borehole motor - Small	0.22 - 22kW	2.2	20	250	400	200	0.5	10	5	2.9
17	Submersible borehole motor - Large	22 - 550kW	37	40	8,000	12,000	200	0.01	15	0.15	2.4
18	Motor + VSD - Very Small	0.15 - 0.75 kW	0.37	220	-	230					
19	Motor + VSD - Small	0.15 - 7.5kW	1.1	320	-	300					
20	Motor + VSD - Medium	7.5 - 75kW	11	1,210	900	1,800					
21	Motor + VSD - Large	75 - 375kW	110	5570	7,200	13,000					
22	Motor + VSD - Very Large	375 - 750kW	550	43290	21,200	32,000					
											223.9

Figure 5.3: Motor and VSD Other model inputs

			Bill of materials (kg)												
Power Range corresponding to	Basecase Size (kW)	Volume m3	Electrical Steel	Other Steel	Cast Iron	Aluminium	Copper	Insulation	Packing	Impregn Resin	Paint	PVC Plastic	PWB	Electronics Small	Electronics Large
0.12 - 0.75 kW	0.37	0.015	5550	925	1221	962	1387.5	370	481	222	48.1	0	0	0	0
0.12 - 0.75 kW	0.37	0.015	3885	777	1221	962	925	24.05	481	148	51.8	0	0	0	0
0.75 - 7.5 kW	1.1	0.02	9922	1804	2750	2332	2486	55	1100	330	110	0	0	0	0
7.5 - 75kW	11	0.15	67210	11550	14300	1221000	11880	220	9900	1100	550	0	0	0	0
75 - 375kW	110	1.1	440000	84700	330000	27500	77000	1100	55000	5500	1100	0	0	0	0
375 - 1,000kW	550	3.2	1100000	220000	880000	110000	165000	3025	151250	15125	3025	0	0	0	0
375 - 1,000kW	550	3.2	1430000	220000	880000	110000	214500	3025	151250	15125	3025	0	0	0	0
0.12 - 0.75 kW	0.37	0.1	0	0	0	481	0	0	0	0	0	148	96.2	96.2	24.05
0.75 - 7.5kW	1.1	0.2	0	550	0	1100	0	0	0	0	0	330	220	220	55
7.5 - 75kW	11	0.5	0	1760	0	2420	0	0	0	0	0	550	330	770	220
75 - 375kW	110	2	0	5500	0	1100	0	0	0	0	0	3300	1100	4400	3300
375 - 750kW	550	5	0	24750	0	4950	0	0	0	0	0	14850	4950	19800	14850
0.22 - 22kW	2.2	0.03	19844	3608	5500	4664	4972	110	2200	660	220				
22 - 550kW	37	0.2	148000	28490	111000	9250	25900	370	18500	1850	370				
0.15 - 0.75 kW	0.37	0.115	3885	777	1221	1443	925	24.05	481	148	51.8	148	96.2	96.2	24.05
0.15 - 7.5kW	1.1	0.22	9922	2354	2750	3432	2486	55	1100	330	110	330	220	220	55
7.5 - 75kW	11	0.65	67210	13310	14300	1223420	11880	220	9900	1100	550	550	330	770	220
75 - 375kW	110	3.1	440000	90200	330000	28600	77000	1100	55000	5500	1100	3300	1100	4400	3300
375 - 750kW	550	8.2	1100000	244750	880000	114950	165000	3025	151250	15125	3025	14850	4950	19800	14850

Figure 5.4: Motor and VSD Bill of Materials

5.1.8 Soft Starter MEEUP Input Data

The following tables show the input data used for the MEEUP models

Basecase Ref	Description	Power Range corresponding to basecase	Basecase Size (kW)	Loss/cycle kW	Cycle time secs	No. starts pa
13	Soft Starter - Small	0.25 - 7.5kW	1.1	0.05	5	2250
14	Soft Starter - Medium	7.5 - 75kW	11	0.5	10	3000
15	Soft Starter - Large	75 - 750kW	110	5	20	6000

Figure 5.5: Soft Starter energy use inputs

Basecase Ref	Description	Basecase Size (kW)	Costs (euros)			Repair Distance (km)	EU Sales pa	Lifetime (Years)	Stock Units	Total Energy use of Stock (TWhpa)
			Installation	Repair	Unit					
13	Soft Starter - Small	1.1	30	0	60	0	1	15	15	
14	Soft Starter - Medium	11	70	100	100	75	0.4	15	6	
15	Soft Starter - Large	110	100	250	800	100	0.4	15	6	

Figure 5.6: Soft starter cost and miscellaneous data

	Bill of materials (kg)												
Basecase Ref	Electrical Steel	Other Steel	Cast Iron	Aluminium	Copper	Insulation	Packing	Impregn Resin	Paint	PVC Plastic	PWB	Electronics Small	Electronics Large
13	0	0	0	715	0	0	0	0	0	220	143	143	35.75
14	0	0	0	5500	0	0	0	0	0	1650	1100	1100	275
15	0	0	0	12100	0	0	0	0	0	2750	1650	3850	1100

Figure 5.7: Soft starter Bill of Materials

5.1.9 Submersible borehole pump motor

The assumed proportion of time spent at each flow is shown in Figure 5.8 below:

Flow	100%	75%	50%	25%
Relative Time	0.3	0.5	0.2	0

Figure 5.8 Submersible borehole pumps: Proportion of time spent at each flow

The material content and costs are based on that for conventional induction motors. This is small source of inaccuracy due to the different dimensional constraints, casing and cooling mechanisms. However, the environmental analysis of other motors shows that material content only has a small impact on overall environmental impact, and so this inaccuracy is not critical.

5.1.10 Motor + VSD

The energy consumption is calculated from the sum of the VSD + motor losses, with an additional increase in motor losses to take account of the impact on motor losses of the VSD. These losses are shown in figure 5.9 below. Note that this calculation does not take account of the wider system energy savings from the use of a VSD, it simply focuses on the internal losses of these motor+controller combinations. A 3-phase motor is assumed in each case.

VSD size (kW)		Loss
VSD - Very Small	0,37	10%
VSD - Small	1,1	10%
VSD - Medium	11	13%
VSD - Large	110	16%
VSD - Very Large (LV and MV)	750	16%

Figure 5.9 Additional motor loss assumed when driven by a VSD (Source:CEMEP)

6 Summary results of Environmental Analysis of Basecases

6.1 Overview

The graphs in section 3.3 present summaries of the environmental emissions of the basecases by environmental factor, by lifecycle stage.

Decisions on possible trade-offs between these different environmental emission factors are outside the remit of this study. Therefore each environmental factor needs to be considered on its own merit, with the focus being on identifying which lifecycle phase has the dominant impact.

For some emissions it is clear what if any elements in the lifecycle can be improved, for others this will require a knowledge of the possible improvements that are possible, which will be described in Task 6. In terms of what improvements are possible, it is the **differences** that are important – and so environmental emissions that are substantially the same irrespective of product performance will be of less interest in the analysis.

It should be stressed that these results are dependent on the assumptions used in the design of the MEEUP model (which cannot be changed), and assumptions underpinning the basecase data.

6.1.1 Soft starters

Soft starters have only very short running hours, due to the fact that these are incurred only during start / stop instances. Because of this, their energy use is extremely small. Technically there is negligible scope for reducing losses, with the possible exception of standby losses, on which there is little data.

The environmental emissions of soft starters are much more diverse than the other products considered, which is simply reflecting the low emissions attributable to energy losses.

→ There is little scope for measures to reduce the energy losses of soft starters, except for standby losses.

6.1.2 Induction motors

For all Motors it is clearly the In-use phase that dominates for each product. The only other significant impact is that of particulates, which relates to the weight and volume of products in distribution. Improved designs using conventional induction motor technology will have a small increase in these factors, but it is thought that any reduction in energy saving would justify the increase in particulates.

Small induction motors have relatively high energy losses due to their proportionately high (kW loss/ kW rated) energy losses. However, the economic potential for energy saving is limited by their lower running hours. It is noted that these products are regulated in the USA, and so it is likely that a similar case can be made for measures in the EU.

Medium induction motors have already been regulated, and so despite their large losses, the scope for further improvement is limited because of the higher (IE2 or IE3) efficiency levels already assumed for the basecase.

Large induction motors use less energy than the small and large segments, but the cost effectiveness of energy savings will be determined by later analysis.

→ The Small induction motor segment appears to have a good energy saving potential. Later analysis will show whether it is technically and economically justifiable to introduce measures to promote medium sized motors at efficiency levels beyond those already included in the" Lot11" regulations.

6.1.3 Variable Speed Drives

The lower relative numbers compared to motors, and the small internal losses of VSDs, means that the total losses are only a small proportion of the total losses for any motor drive system. However, given the large number installed, and the anticipated future growth of the market, the total losses of the stock are significant. Generally only on those below 10kVA is there much room for energy saving, and like soft starters this may relate more to power management and ancillaries rather than losses in the power converter itself. However there are in the market VSDs, with efficiency significantly below average.

VSDs have significant but low quantities of other environmental emissions, which is due to the electronic components used. The particulates in the distribution phase are proportionately high, due mostly to their lower In Use energy losses.

→ VSDs are efficient devices with proportionately little energy losses. Later analysis will show the technical and economic potential for energy savings.

6.1.4 Multistage submersible borehole pump motors

These have a proportionately very small energy use. Even if they are not to be considered for measures within Lot 30, the information is essential for possible Extended Product Approach measures as part of Lot 29.

→ The low energy use and modest energy saving potential mean that Multistage submersible borehole pump motors are a lower priority for regulation, but it may still be practical to regulate them as part of an "Extended Product Approach" for Multistage submersible borehole pumps.

6.1.5 Combined Motor + controller

This basecase has been introduced in order that other new technologies requiring a controller for operation can be compared on a like for like basis; just looking at the energy losses as shown here does not give the full picture. To avoid double counting, energy losses are not included in the pie chart. The basecase of this combination of parts becomes relevant in the context of tasks 6 & 7.

Basecase Ref	Description	Power Range corresponding to	Total Energy Losses of Stock (TWhpa)
1	Small induction motor - 1 phase IE1	0.12 - 0.75 kW	34.9
2	Small induction motor - 3 phase IE1	0.12 - 0.75 kW	22.7
3	Medium induction motor (S) - 3 phase IE2	0.75 - 7.5 kW	27.6
4	Medium induction motor (M) - 3 phase IE2	7.5 - 75kW	36.5
5	Medium induction motor (L) - 3 phase IE2	75 - 375kW	43.0
6	Large induction motor - LV IE2	375 - 1,000kW	18.4
7	Large induction motor - MV IE2	375 - 1,000kW	4.7
8	VSD - Very Small	0.12 - 0.75 kW	7.5
9	VSD - Small	0.75 - 7.5kW	6.2
10	VSD - Medium	7.5 - 75kW	3.2
11	VSD - Large	75 - 375kW	2.2
12	VSD - Very Large	375 - 750kW	11.7
16	Submersible borehole motor - Small	0.22 - 22kW	2.9
17	Submersible borehole motor - Large	22 - 550kW	2.4
18	Motor + VSD - Very Small	0.15 - 0.75 kW	
19	Motor + VSD - Small	0.15 - 7.5kW	
20	Motor + VSD - Medium	7.5 - 75kW	
21	Motor + VSD - Large	75 - 375kW	
22	Motor + VSD - Very Large	375 - 750kW	
			223.9

Figure 5.10 Breakdown of energy losses, by product.

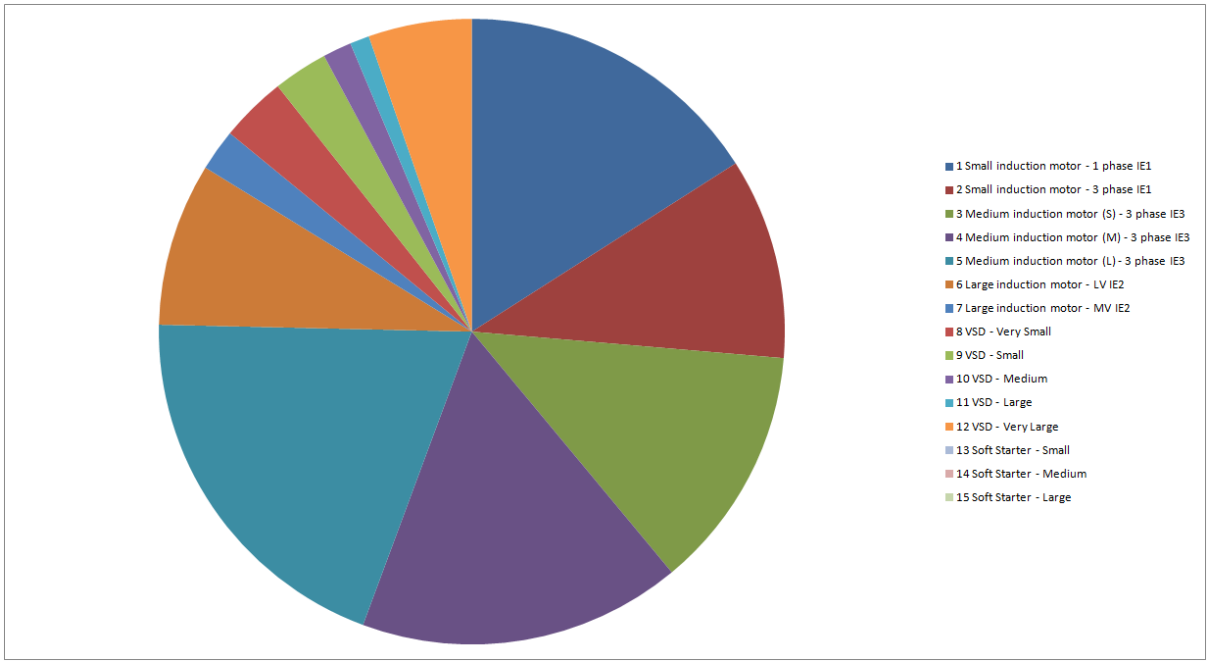


Figure 5.11 Breakdown of energy losses, by product.

6.2 Summary of lifetime environmental impacts, by basecase

6.2.1 Basecase 1 Small Induction Motor – I phase IE1 0.37kW

Nr	Life cycle Impact per product:	Date	Author
1	Small induction motor - 1 phase IE1	V3.0 19 Dec 2013	HF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**222**			200	22	**222**	**0**
3	Ferro	g			**7696**			385	7311	**7696**	**0**
4	Non-ferro	g			**2350**			117	2232	**2350**	**0**
5	Coating	g			**48**			2	46	**48**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**851**			43	808	**851**	**0**
	Total weight	g			**11167**			747	10420	**11167**	**0**
	Other Resources & Waste							debet	credit (see note!)		
8	Total Energy (GER)	MJ	446	18	**464**	**72**	**4077**	52	23	**29**	**4642**
9	of which, electricity (in primary MJ)	MJ	40	11	**51**	**0**	**4073**	0	0	**0**	**4124**
10	Water (process)	ltr	13	0	**13**	**0**	**272**	0	0	**0**	**284**
11	Water (cooling)	ltr	108	5	**113**	**0**	**10861**	0	0	**0**	**10974**
12	Waste, non-haz./ landfill	g	34255	56	**34311**	**61**	**5065**	685	0	**684**	**40122**
13	Waste, hazardous/ incinerated	g	6	0	**6**	**1**	**94**	200	0	**200**	**301**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq	27	1	**28**	**6**	**178**	4	2	**2**	**214**
15	Ozone Depletion, emissions	mg R-11eq	negligible								
16	Acidification, emissions	g SO2 eq.	477	4	**482**	**16**	**1053**	8	2	**6**	**1557**
17	Volatile Organic Compounds (VOC)	g	1	0	**1**	**0**	**2**	0	0	**0**	**3**
18	Persistent Organic Pollutants (POP)	ng i-Teq	123	0	**123**	**0**	**28**	5	0	**5**	**156**
19	Heavy Metals	mg Ni eq.	98	0	**98**	**3**	**71**	15	0	**15**	**187**
	PAHs	mg Ni eq.	25	0	**25**	**3**	**8**	0	0	**0**	**36**
20	Particulate Matter (PM, dust)	g	36	1	**36**	**52**	**23**	67	0	**67**	**178**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	27	0	**27**	**0**	**27**	4	0	**4**	**57**
22	Eutrophication	g PO4	3	0	**3**	**0**	**0**	0	0	**0**	**4**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

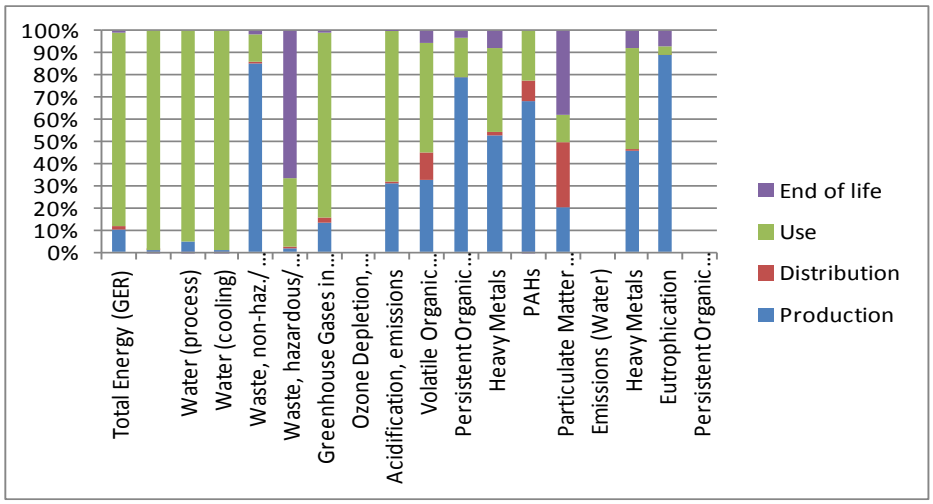


Figure 5.12 Basecase 1, Small induction motor – 1 phase IE1: Breakdown of environmental impact, by type and life cycle phase

6.2.2 Basecase 2 Small induction motor – 3 phase IE1 0.37kW

Nr	Life cycle Impact per product:											Date	Author
2	Small induction motor - 3 phase IE1											V3.0 19 Dec 2013	HF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	BUTION		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**148**			133	15	**148**	**0**
3	Ferro	g			**5883**			294	5589	**5883**	**0**
4	Non-ferro	g			**1887**			94	1793	**1887**	**0**
5	Coating	g			**52**			3	49	**52**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**505**			25	480	**505**	**0**
	Total weight	g			**8475**			550	7925	**8475**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	330	15	**345**	**72**	**20366**	38	15	**23**	**20806**
9	of which, electricity (in primary MJ)	MJ	29	9	**38**	**0**	**20363**	0	0	**0**	**20401**
10	Water (process)	ltr	9	0	**9**	**0**	**1358**	0	0	**0**	**1367**
11	Water (cooling)	ltr	81	4	**85**	**0**	**54301**	0	0	**0**	**54386**
12	Waste, non-haz./ landfill	g	23488	47	**23535**	**61**	**23845**	520	0	**519**	**47960**
13	Waste, hazardous/ incinerated	g	5	0	**5**	**1**	**469**	133	0	**133**	**608**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq	20	1	**21**	**6**	**889**	3	1	**2**	**917**
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	327	4	**331**	**16**	**5247**	6	1	**4**	**5597**
17	Volatile Organic Compounds (VOC)	g	1	0	**1**	**0**	**8**	0	0	**0**	**9**
18	Persistent Organic Pollutants (POP)	ng i-Teq	99	0	**99**	**0**	**134**	4	0	**4**	**238**
19	Heavy Metals	mg Ni eq.	68	0	**68**	**3**	**350**	11	0	**11**	**432**
	PAHs	mg Ni eq.	22	0	**22**	**3**	**40**	0	0	**0**	**66**
20	Particulate Matter (PM, dust)	g	31	1	**32**	**52**	**112**	49	0	**49**	**245**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	21	0	**21**	**0**	**131**	3	0	**3**	**155**
22	Eutrophication	g PO4	2	0	**2**	**0**	**1**	0	0	**0**	**3**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

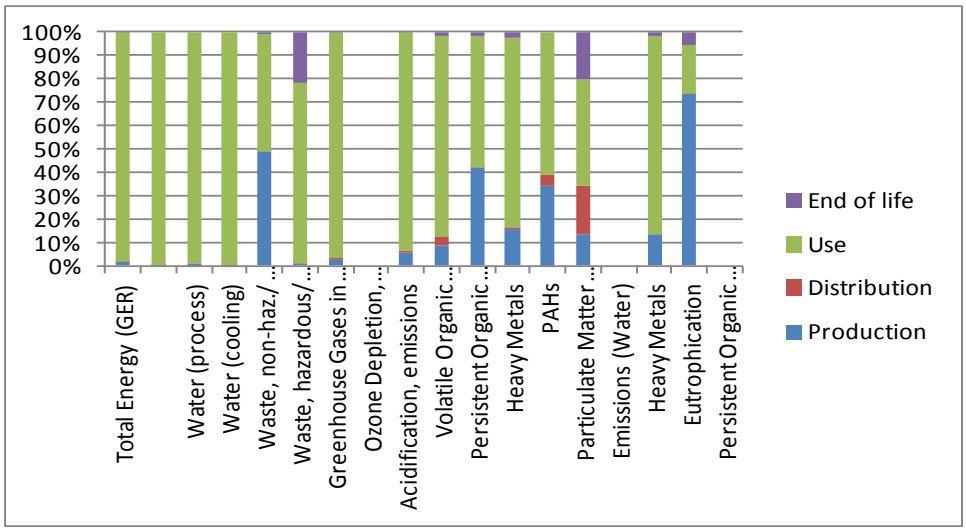


Figure 5.13: Basecase 2, Small induction motor – 3 phase IE1: Breakdown of environmental impact, by type and life cycle phase

6.2.3 Basecase 3 Medium induction motor (S) - 3 phase IE2 1.1kW

Nr	Life cycle Impact per product:	Date	Author
3	Medium induction motor (S) - 3 phase IE2	V3.0 19 Dec 2013	HF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**330**			297	33	**330**	**0**
3	Ferro	g			**14476**			724	13752	**14476**	**0**
4	Non-ferro	g			**4818**			241	4577	**4818**	**0**
5	Coating	g			**110**			6	105	**110**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**1155**			58	1097	**1155**	**0**
	Total weight	g			**20889**			1325	19564	**20889**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	828	35	**863**	**79**	**43470**	92	33	**58**	**44470**
9	of which, electricity (in primary MJ)	MJ	71	21	**92**	**0**	**43462**	0	0	**0**	**43554**
10	Water (process)	ltr	20	0	**20**	**0**	**2898**	0	0	**0**	**2918**
11	Water (cooling)	ltr	179	10	**189**	**0**	**115898**	0	1	**-1**	**116086**
12	Waste, non-haz./ landfill	g	62073	109	**62182**	**64**	**51012**	1281	0	**1280**	**114539**
13	Waste, hazardous/ incinerated	g	11	0	**11**	**1**	**1002**	297	0	**297**	**1310**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq	51	2	**52**	**6**	**1897**	7	2	**4**	**1960**
15	Ozone Depletion, emissions	mg R-11eq	negligible								
16	Acidification, emissions	g SO2 eq.	865	8	**874**	**17**	**11200**	13	3	**10**	**12101**
17	Volatile Organic Compounds (VOC)	g	2	0	**2**	**0**	**16**	0	0	**0**	**19**
18	Persistent Organic Pollutants (POP)	ng i-Teq	245	0	**245**	**0**	**287**	9	0	**9**	**542**
19	Heavy Metals	mg Ni eq.	178	0	**178**	**3**	**747**	26	0	**26**	**955**
	PAHs	mg Ni eq.	55	0	**55**	**4**	**86**	0	0	**0**	**145**
20	Particulate Matter (PM, dust)	g	74	1	**75**	**69**	**240**	119	0	**119**	**503**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	52	0	**52**	**0**	**281**	8	0	**8**	**341**
22	Eutrophication	g PO4	5	0	**5**	**0**	**1**	0	0	**0**	**7**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

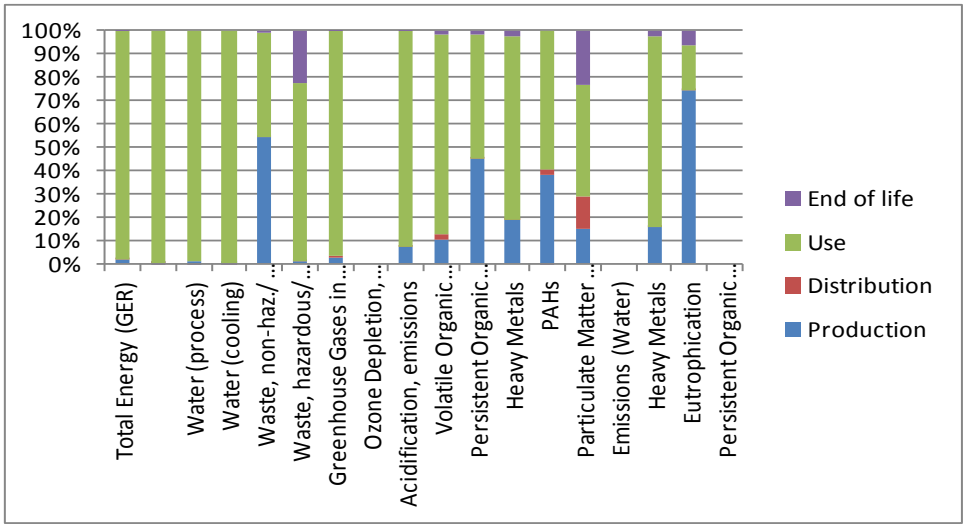


Figure 5.14: Basecase 3, Medium induction motor (S) - 3 phase IE3: Breakdown of environmental impact, by type and life cycle phase.

6.2.4 Basecase 4 Medium induction motor (M) - 3 phase IE2 11kW

Nr	Life cycle Impact per product:	Date	Author
4	Medium induction motor (M) - 3 phase IE2	V3.0 19 Dec 2013	HF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**1100**			990	110	**1100**	**0**
3	Ferro	g			**93060**			4653	88407	**93060**	**0**
4	Non-ferro	g			**24090**			1205	22886	**24090**	**0**
5	Coating	g			**550**			28	523	**550**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**10120**			506	9614	**10120**	**0**
	Total weight	g			**128920**			7381	121539	**128920**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	4485	156	**4641**	**255**	**286394**	508	203	**305**	**291596**
9	of which, electricity (in primary MJ)	MJ	443	94	**537**	**0**	**286173**	0	0	**0**	**286710**
10	Water (process)	ltr	121	1	**123**	**0**	**19079**	0	0	**0**	**19201**
11	Water (cooling)	ltr	686	44	**730**	**0**	**763120**	0	2	**-2**	**763848**
12	Waste, non-haz./ landfill	g	316051	488	**316539**	**149**	**334960**	7903	2	**7901**	**659550**
13	Waste, hazardous/ incinerated	g	42	0	**42**	**3**	**6595**	990	0	**990**	**7630**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq	278	9	**287**	**17**	**12505**	38	15	**23**	**12832**
15	Ozone Depletion, emissions	mg R-11eq	negligible								
16	Acidification, emissions	g SO2 eq.	4223	37	**4260**	**49**	**73745**	75	19	**56**	**78110**
17	Volatile Organic Compounds (VOC)	g	12	0	**12**	**3**	**111**	2	0	**2**	**128**
18	Persistent Organic Pollutants (POP)	ng i-Teq	1487	0	**1487**	**1**	**1891**	54	0	**54**	**3433**
19	Heavy Metals	mg Ni eq.	915	0	**915**	**8**	**4958**	147	0	**147**	**6027**
	PAHs	mg Ni eq.	285	0	**285**	**9**	**606**	0	0	**0**	**899**
20	Particulate Matter (PM, dust)	g	390	6	**395**	**513**	**2239**	661	0	**660**	**3808**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	293	0	**293**	**0**	**1848**	42	0	**42**	**2183**
22	Eutrophication	g PO4	22	0	**22**	**0**	**9**	2	0	**2**	**34**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

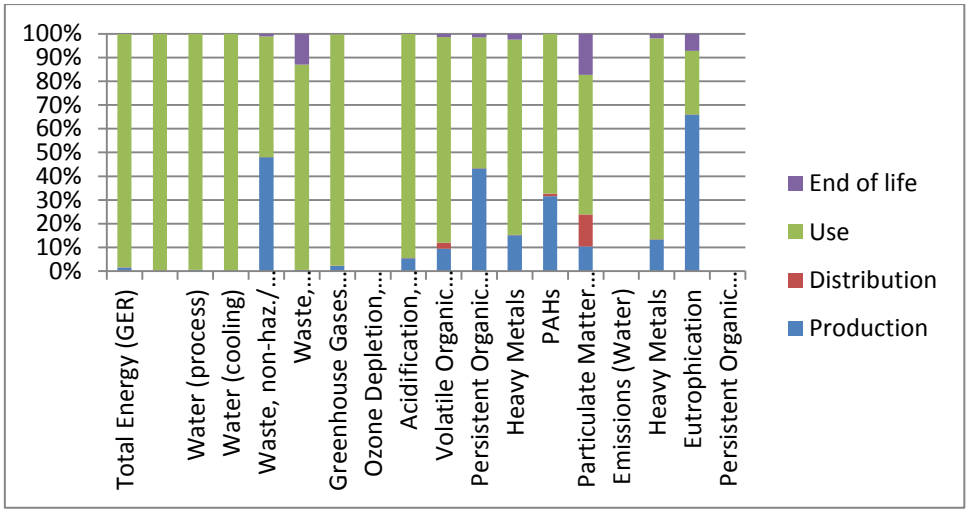


Figure 5.15: Basecase 4, Medium induction motor (M) - 3 phase IE3: Breakdown of environmental impact, by type and life cycle phase.

6.2.5 Basecase 5 Medium induction motor (L) - 3 phase IE2 110kW

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	kt			**0**			0	0	**0**	**0**
2	TecPlastics	kt			**1**			0	0	**1**	**0**
3	Ferro	kt			**85**			4	81	**85**	**0**
4	Non-ferro	kt			**10**			1	10	**10**	**0**
5	Coating	kt			**0**			0	0	**0**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**6**			0	5	**6**	**0**
	Total weight	kt			**102**			6	97	**102**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	3	0	**3**	**0**	**452**	0	0	**0**	**455**
9	of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**452**	0	0	**0**	**452**
10	Water (process)	mln. m3	0	0	**0**	**0**	**30**	0	0	**0**	**30**
11	Water (cooling)	mln. m3	0	0	**0**	**0**	**1205**	0	0	**0**	**1206**
12	Waste, non-haz./ landfill	kt	209	0	**210**	**0**	**526**	6	0	**6**	**742**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**10**	0	0	**0**	**11**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq	0	0	**0**	**0**	**20**	0	0	**0**	**20**
15	Ozone Depletion, emissions	t R-11eq.	negligible								
16	Acidification, emissions	kt SO2 eq.	3	0	**3**	**0**	**116**	0	0	**0**	**119**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	1	0	**1**	**0**	**3**	0	0	**0**	**4**
19	Heavy Metals	ton Ni eq.	1	0	**1**	**0**	**8**	0	0	**0**	**9**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**1**	0	0	**0**	**1**
20	Particulate Matter (PM, dust)	kt	1	0	**1**	**0**	**3**	0	0	**0**	**4**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	**0**	**0**	**3**	0	0	**0**	**3**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq	negligible								

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

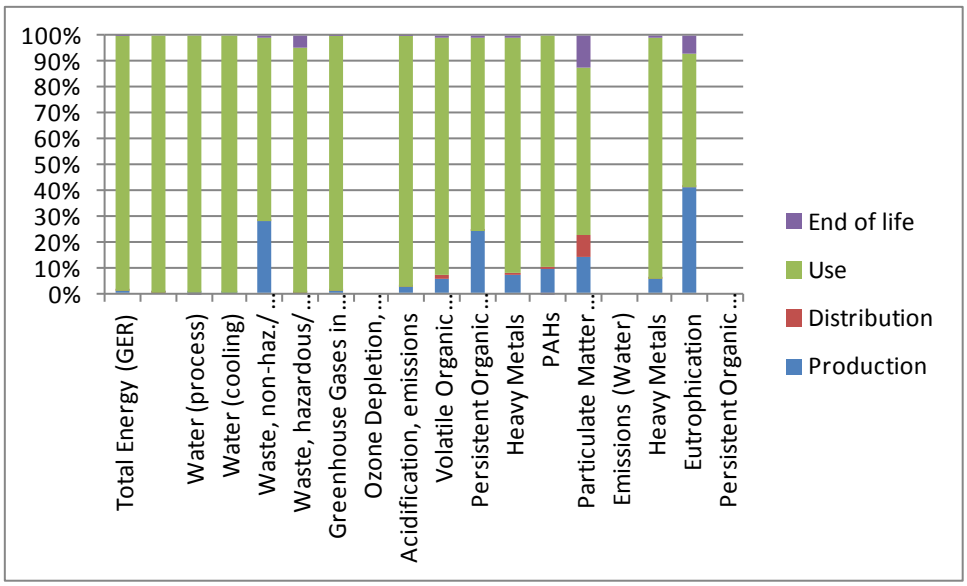


Figure 5.16: Basecase 5, Medium induction motor (L) - 3 phase IE3: Breakdown of environmental impact, by type and life cycle phase.

6.2.6 Basecase 6 Large induction motor – LV IE2 550kW

Nr	Life cycle Impact per product:	Date	Author
6	Large induction motor - LV IE2	V3.0 19 Dec 2013	HF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	BUTION		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**15125**			13613	1513	**15125**	**0**
3	Ferro	g			**2200000**			110000	2090000	**2200000**	**0**
4	Non-ferro	g			**275000**			13750	261250	**275000**	**0**
5	Coating	g			**3025**			151	2874	**3025**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**154275**			7714	146561	**154275**	**0**
	Total weight	g			**2647425**			145228	2502198	**2647425**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	68382	3266	**71648**	**4394**	**19332757**	9970	2760	**7210**	**19416009**
9	of which, electricity (in primary MJ)	MJ	7019	1966	**8985**	**9**	**19331649**	0	6	**-6**	**19340638**
10	Water (process)	ltr	2576	30	**2606**	**0**	**1288797**	0	4	**-4**	**1291399**
11	Water (cooling)	ltr	10190	927	**11118**	**0**	**51550937**	0	32	**-32**	**51562023**
12	Waste, non-haz./ landfill	g	4739225	10233	**4749458**	**2145**	**22461341**	162284	22	**162262**	**27375206**
13	Waste, hazardous/ incinerated	g	489	0	**489**	**43**	**445461**	13613	4	**13609**	**459601**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq	4613	181	**4795**	**261**	**843704**	744	202	**542**	**849301**
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	60454	781	**61235**	**802**	**4978526**	1463	255	**1208**	**5041771**
17	Volatile Organic Compounds (VOC)	g	272	0	**272**	**67**	**7291**	40	3	**36**	**7666**
18	Persistent Organic Pollutants (POP)	ng i-Teq	25463	0	**25463**	**12**	**126965**	1117	0	**1117**	**153557**
19	Heavy Metals	mg Ni eq.	14586	0	**14586**	**109**	**331907**	2895	0	**2895**	**349496**
	PAHs	mg Ni eq.	2914	0	**2914**	**144**	**38217**	0	0	**0**	**41275**
20	Particulate Matter (PM, dust)	g	14864	120	**14985**	**10941**	**108237**	12974	5	**12969**	**147133**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	4652	0	**4652**	**3**	**124691**	829	0	**829**	**130175**
22	Eutrophication	g PO4	288	2	**290**	**0**	**597**	47	0	**47**	**935**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

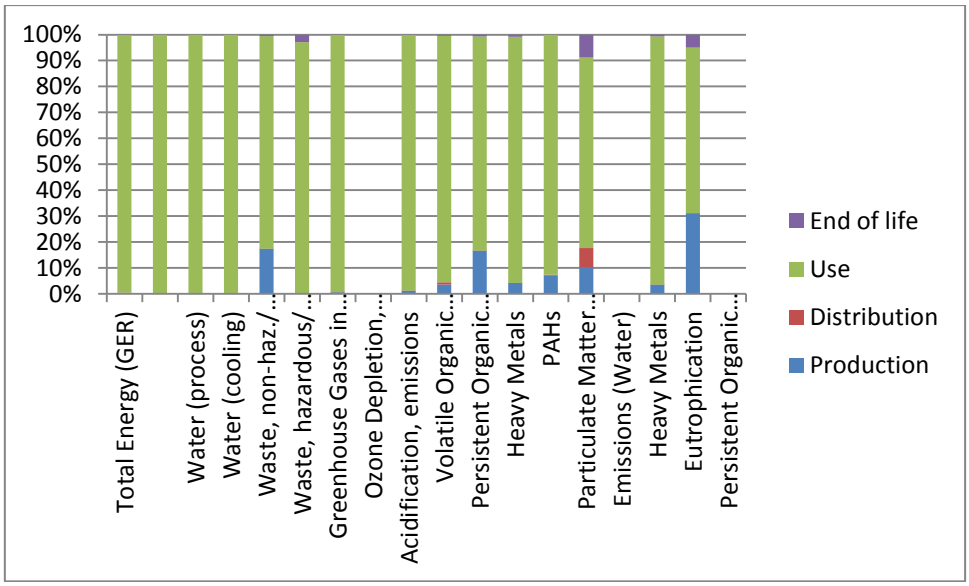


Figure 5.17: Basecase 6, Large induction motor – LV IE2: Breakdown of environmental impact, by type and life cycle phase.

6.2.7 Basecase 7 Large induction motor – MV IE2 550kW

Nr	Life cycle Impact per product:								Date	Author
7	Large induction motor - MV IE2								V3.0 19 Dec 2013	HF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	BUTION		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**13750**			12375	1375	**13750**	**0**
3	Ferro	g			**2300000**			115000	2185000	**2300000**	**0**
4	Non-ferro	g			**295000**			14750	280250	**295000**	**0**
5	Coating	g			**2750**			138	2613	**2750**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**140250**			7013	133238	**140250**	**0**
	Total weight	g			**2751750**			149275	2602475	**2751750**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	73688	2969	**76657**	**4394**	**14947256**	10242	2466	**7776**	**15036082**
9	of which, electricity (in primary MJ)	MJ	7753	1787	**9540**	**9**	**14946103**	0	5	**-5**	**14955647**
10	Water (process)	ltr	2342	27	**2369**	**0**	**996424**	0	3	**-3**	**998790**
11	Water (cooling)	ltr	9264	843	**10107**	**0**	**39856122**	0	29	**-29**	**39866200**
12	Waste, non-haz./ landfill	g	5450392	9303	**5459695**	**2145**	**17383645**	168678	20	**168658**	**23014143**
13	Waste, hazardous/ incinerated	g	480	0	**480**	**43**	**344405**	12375	3	**12372**	**357300**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq	4938	165	**5103**	**261**	**652324**	764	180	**584**	**658271**
15	Ozone Depletion, emissions	mg R-11 eq	negligible								
16	Acidification, emissions	g SO2 eq.	69709	710	**70419**	**802**	**3849338**	1502	228	**1274**	**3921834**
17	Volatile Organic Compounds (VOC)	g	284	0	**284**	**67**	**5640**	41	3	**38**	**6028**
18	Persistent Organic Pollutants (POP)	ng i-Teq	26927	0	**26927**	**12**	**98234**	1161	0	**1161**	**126334**
19	Heavy Metals	mg Ni eq.	16579	0	**16579**	**109**	**256687**	2976	0	**2976**	**276352**
	PAHs	mg Ni eq.	2908	0	**2908**	**144**	**29577**	0	0	**0**	**32629**
20	Particulate Matter (PM, dust)	g	13950	110	**14060**	**10941**	**84108**	13329	4	**13325**	**122433**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	4991	0	**4991**	**3**	**96417**	851	0	**851**	**102263**
22	Eutrophication	g PO4	281	2	**282**	**0**	**462**	49	0	**49**	**793**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

"=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

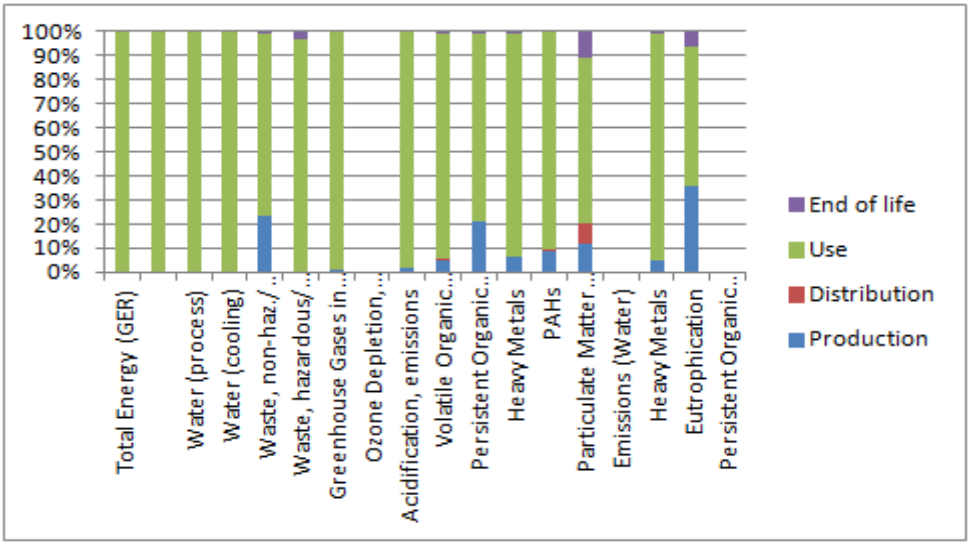


Figure 5.18: Basecase 7, Large induction motor – MV IE2: Breakdown of environmental impact, by type and life cycle phase.

6.2.8 Basecase 8 VSD Very small 0.37kW

Nr	Life cycle Impact per product:	Date	Author
8	VSD - Very Small	V2.0 27 Nov 2013	HF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			148			133	15	148	0
2	TecPlastics	g			0			0	0	0	0
3	Ferro	g			0			0	0	0	0
4	Non-ferro	g			481			24	457	481	0
5	Coating	g			0			0	0	0	0
6	Electronics	g			216			108	108	216	0
7	Misc.	g			0			0	0	0	0
	Total weight	g			845			265	580	845	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	673	43	716	187	4358	19	24	-5	5255
9	of which, electricity (in primary MJ)	MJ	531	9	540	0	4356	0	13	-13	4884
10	Water (process)	ltr	501	3	504	0	295	0	11	-11	788
11	Water (cooling)	ltr	33	12	45	0	11602	0	3	-3	11644
12	Waste, non-haz./ landfill	g	2665	87	2751	117	5072	52	37	15	7955
13	Waste, hazardous/ incinerated	g	193	1	194	2	102	241	14	227	526
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq	48	3	50	13	190	1	2	0	253
15	Ozone Depletion, emissions	mg R-11 e	negligible								
16	Acidification, emissions	g SO2 eq	327	14	341	37	1124	3	10	-7	1494
17	Volatile Organic Compounds (VOC)	g	7	1	7	2	2	0	0	0	11
18	Persistent Organic Pollutants (POP)	ng i-Teq	7	1	9	1	29	0	0	0	38
19	Heavy Metals	mg Ni eq	48	3	52	6	75	5	2	4	136
	PAHs	mg Ni eq	53	1	54	7	9	0	1	-1	69
20	Particulate Matter (PM, dust)	g	17	4	21	342	24	25	1	24	411
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	380	0	380	0	32	2	7	-6	407
22	Eutrophication	g PO4	3	0	3	0	0	0	0	0	3
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

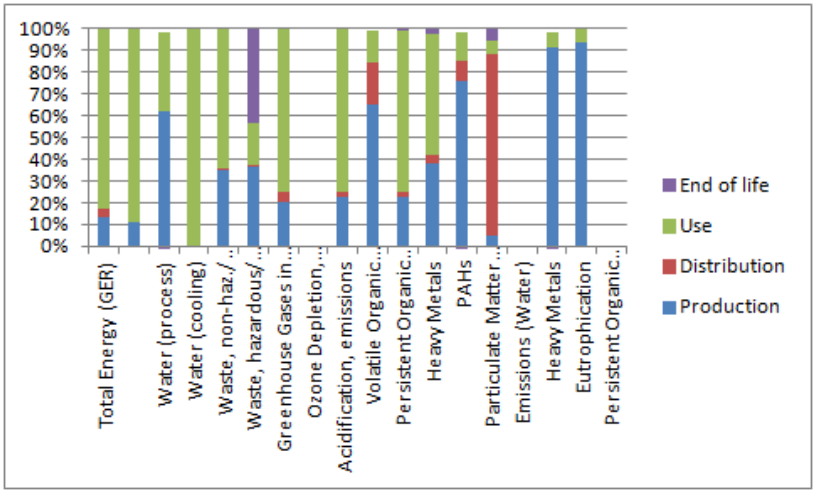


Figure 5.19: Basecase 8, VSD – Very small: Breakdown of environmental impact, by type and life cycle phase.

6.2.9 Basecase 9 VSD Small 1.1kW

Nr	Life cycle Impact per product:								Date	Author
9	VSD - Small								V2.0 27 Nov 2013	HF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			330			297	33	330	0
2	TecPlastics	g			0			0	0	0	0
3	Ferro	g			550			28	523	550	0
4	Non-ferro	g			1100			55	1045	1100	0
5	Coating	g			0			0	0	0	0
6	Electronics	g			495			248	248	495	0
7	Misc.	g			0			0	0	0	0
	Total weight	g			2475			627	1848	2475	0
									see note!		
	Other Resources & Waste								debet	credit	
8	Total Energy (GER)	MJ	1548	97	1645	323	11453	45	56	-10	13410
9	of which, electricity (in primary MJ)	MJ	1217	21	1238	1	11449	0	29	-29	12659
10	Water (process)	ltr	1146	6	1152	0	774	0	26	-26	1900
11	Water (cooling)	ltr	74	26	101	0	30499	0	6	-6	30594
12	Waste, non-haz./ landfill	g	6533	197	6730	182	13328	152	84	68	20308
13	Waste, hazardous/ incinerated	g	441	2	443	4	268	545	32	512	1227
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq	110	6	116	21	500	3	4	0	637
15	Ozone Depletion, emissions	mg R-11 e				negligible					
16	Acidification, emissions	g SO2 eq	750	32	782	61	2953	7	23	-16	3780
17	Volatile Organic Compounds (VOC)	g	16	2	17	4	4	0	0	0	26
18	Persistent Organic Pollutants (POP)	ng i-Teq	24	3	27	1	75	1	0	1	104
19	Heavy Metals	mg Ni eq	112	7	119	9	197	12	4	9	335
	PAHs	mg Ni eq	122	1	123	11	24	0	3	-3	156
20	Particulate Matter (PM, dust)	g	39	9	48	684	63	58	1	57	852
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	870	0	870	0	82	4	16	-13	940
22	Eutrophication	g PO4	6	0	6	0	0	0	0	0	7
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

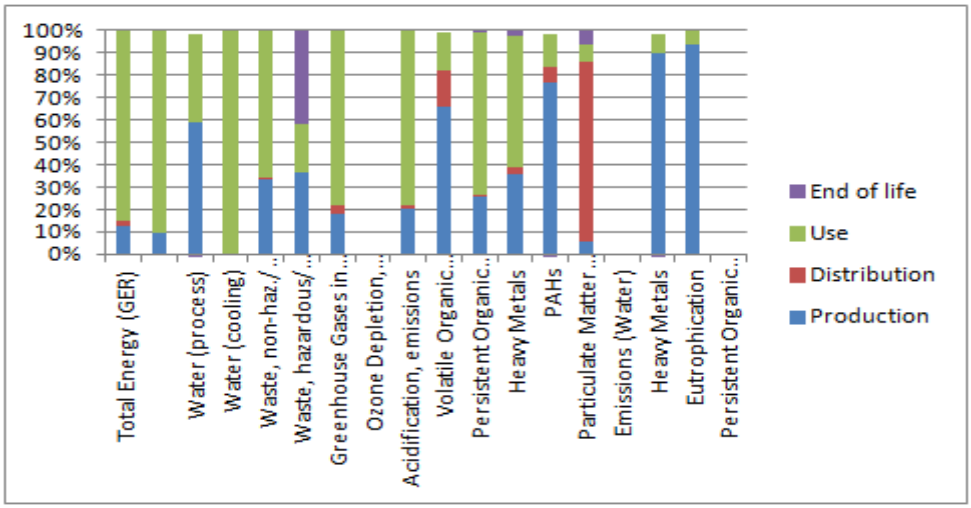


Figure 5.20: Basecase 9, VSD - Small: Breakdown of environmental impact, by type and life cycle phase.

6.2.10 Basecase 10 VSD Medium 11kW

Nr	Life cycle Impact per product:	Date	Author
10	VSD - Medium	V2.0 27 Nov 2013	HF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			550			495	55	550	0
2	TecPlastics	g			0			0	0	0	0
3	Ferro	g			1760			88	1672	1760	0
4	Non-ferro	g			2420			121	2299	2420	0
5	Coating	g			0			0	0	0	0
6	Electronics	g			1320			660	660	1320	0
7	Misc.	g			0			0	0	0	0
	Total weight	g			6050			1364	4686	6050	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	4968	236	5203	730	102661	99	131	-32	108563
9	of which, electricity (in primary MJ)	MJ	4188	43	4230	1	102471	0	77	-77	106626
10	Water (process)	ltr	3932	16	3948	0	6868	0	69	-69	10747
11	Water (cooling)	ltr	128	64	192	0	273145	0	15	-15	273322
12	Waste, non-haz./ landfill	g	15934	435	16369	378	118924	371	223	148	135820
13	Waste, hazardous/ incinerated	g	776	6	781	8	2368	1155	86	1069	4226
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq	364	15	379	45	4488	7	9	-1	4910
15	Ozone Depletion, emissions	mg R-11 e	negligible								
16	Acidification, emissions	g SO2 eq	2427	81	2508	136	26414	15	60	-46	29012
17	Volatile Organic Compounds (VOC)	g	53	4	57	10	42	0	1	-1	109
18	Persistent Organic Pollutants (POP)	ng i-Teq	72	7	79	2	672	3	1	2	755
19	Heavy Metals	mg Ni eq	371	16	387	19	1800	27	10	17	2224
	PAHs	mg Ni eq	292	3	296	25	244	0	8	-8	556
20	Particulate Matter (PM, dust)	g	110	22	132	1710	1226	126	3	123	3192
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	2990	1	2990	1	690	8	44	-36	3645
22	Eutrophication	g PO4	18	1	19	0	3	0	1	0	22
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

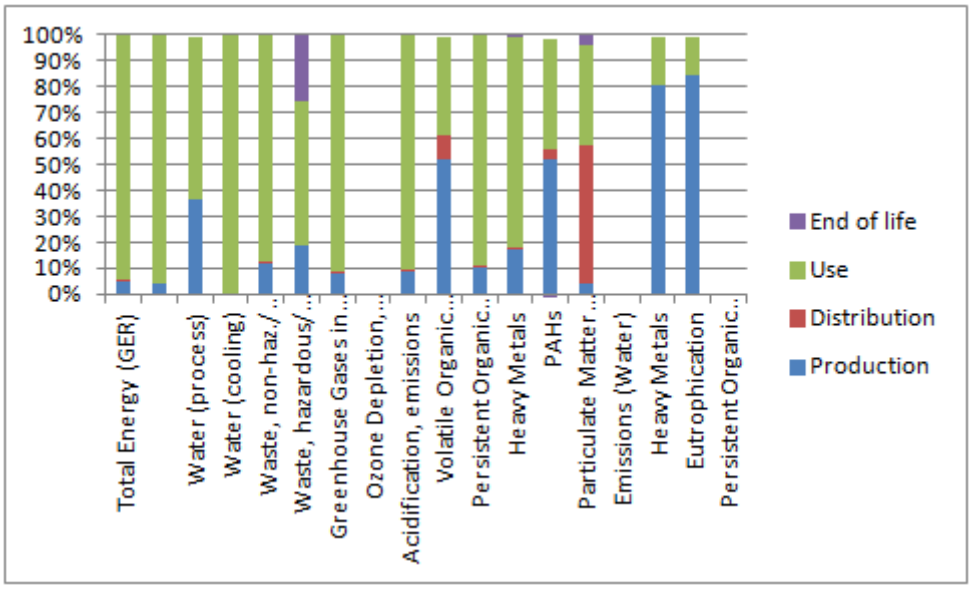


Figure 5.21: Basecase 10, VSD - Medium: Breakdown of environmental impact, by type and life cycle phase.

6.2.11 Basecase 11 VSD Large 110kW

Nr	Life cycle Impact per product:	Date	Author
10	VSD - Medium	V2.0 27 Nov 2013	HF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			550			495	55	550	0
2	TecPlastics	g			0			0	0	0	0
3	Ferro	g			1760			88	1672	1760	0
4	Non-ferro	g			2420			121	2299	2420	0
5	Coating	g			0			0	0	0	0
6	Electronics	g			1320			660	660	1320	0
7	Misc.	g			0			0	0	0	0
	Total weight	g			6050			1364	4686	6050	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	4968	236	5203	730	102661	99	131	-32	108563
9	of which, electricity (in primary MJ)	MJ	4188	43	4230	1	102471	0	77	-77	106626
10	Water (process)	ltr	3932	16	3948	0	6868	0	69	-69	10747
11	Water (cooling)	ltr	128	64	192	0	273145	0	15	-15	273322
12	Waste, non-haz./ landfill	g	15934	435	16369	378	118924	371	223	148	135820
13	Waste, hazardous/ incinerated	g	776	6	781	8	2368	1155	86	1069	4226
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq	364	15	379	45	4488	7	9	-1	4910
15	Ozone Depletion, emissions	mg R-11 e	negligible								
16	Acidification, emissions	g SO2 eq	2427	81	2508	136	26414	15	60	-46	29012
17	Volatile Organic Compounds (VOC)	g	53	4	57	10	42	0	1	-1	109
18	Persistent Organic Pollutants (POP)	ng i-Teq	72	7	79	2	672	3	1	2	755
19	Heavy Metals	mg Ni eq	371	16	387	19	1800	27	10	17	2224
	PAHs	mg Ni eq	292	3	296	25	244	0	8	-8	556
20	Particulate Matter (PM, dust)	g	110	22	132	1710	1226	126	3	123	3192
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	2990	1	2990	1	690	8	44	-36	3645
22	Eutrophication	g PO4	18	1	19	0	3	0	1	0	22
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

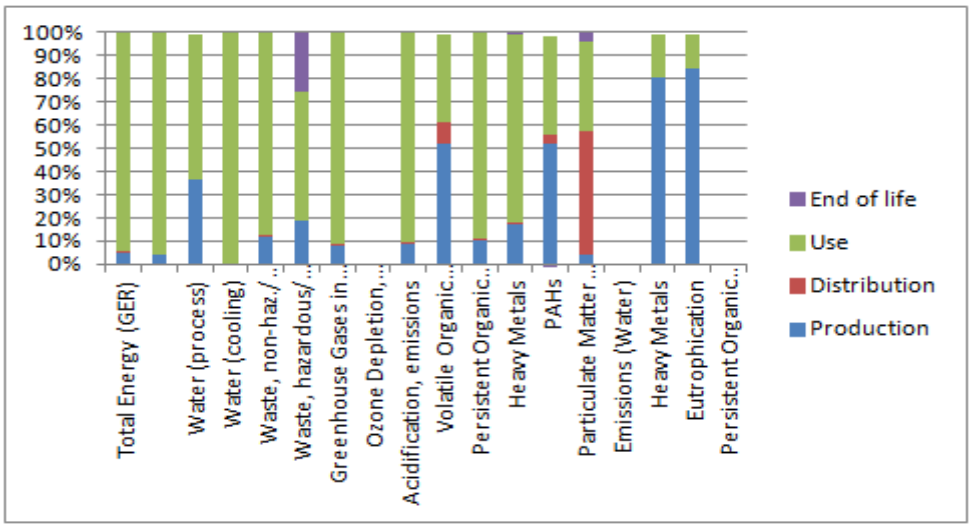


Figure 5.22: Basecase 11,VSD - Large: Breakdown of environmental impact, by type and life cycle phase.

6.2.12 Basecase 12 VSD Very Large 550kW

Nr	Life cycle Impact per product:								Date	Author	
12	VSD - Very Large								V2.0 27 Nov 2013	HF	

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			14850			13365	1485	14850	0
2	TecPlastics	g			0			0	0	0	0
3	Ferro	g			24750			1238	23513	24750	0
4	Non-ferro	g			4950			248	4703	4950	0
5	Coating	g			0			0	0	0	0
6	Electronics	g			39600			19800	19800	39600	0
7	Misc.	g			0			0	0	0	0
	Total weight	g			84150			34650	49500	84150	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	118952	5784	124737	6837	7459741	2529	3816	-1287	7590028
9	of which, electricity (in primary MJ)	MJ	107058	543	107601	14	7459329	0	2300	-2300	7564645
10	Water (process)	ltr	100831	473	101304	0	498230	0	2076	-2076	597458
11	Water (cooling)	ltr	3647	1610	5257	0	19888728	0	450	-450	19893535
12	Waste, non-haz./ landfill	g	165092	6587	171680	3323	8649138	5163	6673	-1510	8822630
13	Waste, hazardous/ incinerated	g	14005	167	14173	66	172002	33165	2587	30578	216818
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq	8896	376	9273	405	325585	189	254	-65	335197
15	Ozone Depletion, emissions	mg R-11 e	negligible								
16	Acidification, emissions	g SO2 eq	59039	2108	61147	1247	1921130	377	1797	-1420	1982105
17	Volatile Organic Compounds (VOC)	g	1358	123	1481	104	2828	6	26	-20	4393
18	Persistent Organic Pollutants (POP)	ng i-Teq	1334	17	1351	19	48899	37	25	11	50281
19	Heavy Metals	mg Ni eq	9217	66	9283	169	128100	683	291	392	137944
	PAHs	mg Ni eq	3853	102	3956	224	14784	0	239	-239	18725
20	Particulate Matter (PM, dust)	g	2148	621	2769	17096	41930	3229	90	3139	64934
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	75468	17	75485	5	48843	212	1320	-1108	123226
22	Eutrophication	g PO4	454	28	482	0	234	12	19	-7	710
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

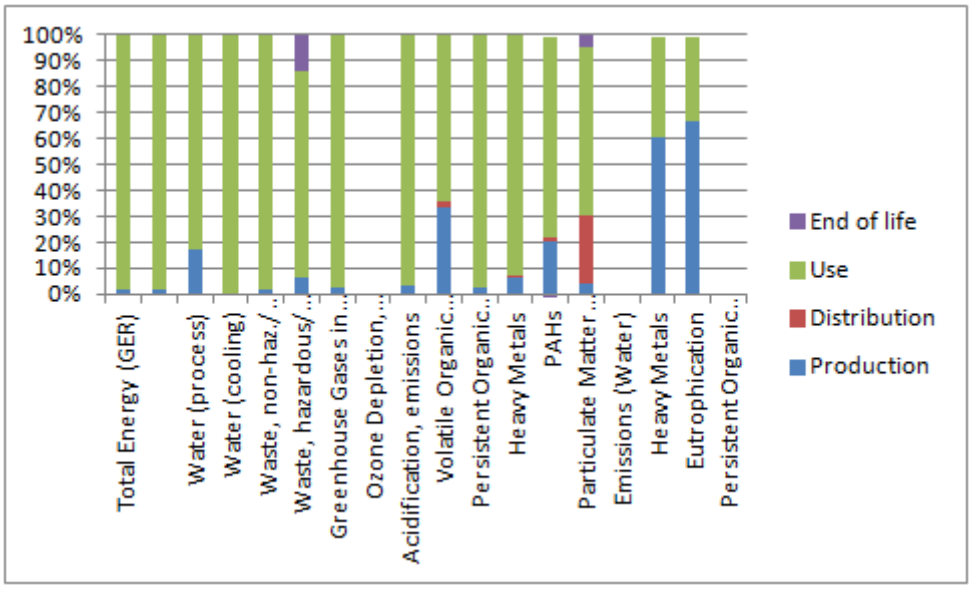


Figure 5.23: Basecase 12, VSD – Very large: Breakdown of environmental impact, by type and life cycle phase.

6.2.13 Basecase 13 Soft Starter Small 1.1kW

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**220**			198	22	**220**	**0**
2	TecPlastics	g			**0**			0	0	**0**	**0**
3	Ferro	g			**0**			0	0	**0**	**0**
4	Non-ferro	g			**715**			36	679	**715**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**322**			161	161	**322**	**0**
7	Misc.	g			**0**			0	0	**0**	**0**
	Total weight	g			**1257**			395	862	**1257**	**0**
									see note!		
	Other Resources & Waste							debit	credit		
8	Total Energy (GER)	MJ	1000	63	**1064**	**459**	**35**	29	36	**-8**	**1550**
9	of which, electricity (in primary PJ)	MJ	789	14	**803**	**1**	**33**	0	19	**-19**	**818**
10	Water (process)	ltr	745	4	**749**	**0**	**9**	0	17	**-17**	**741**
11	Water (cooling)	ltr	49	17	**66**	**0**	**66**	0	4	**-4**	**129**
12	Waste, non-haz./ landfill	g	3961	129	**4089**	**248**	**69**	77	54	**23**	**4429**
13	Waste, hazardous/ incinerated	g	287	1	**288**	**5**	**3**	359	21	**338**	**634**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.									
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	486	21	**507**	**86**	**11**	4	15	**-11**	**594**
17	Volatile Organic Compounds (VOC)	g	10	1	**11**	**6**	**0**	0	0	**0**	**17**
18	Persistent Organic Pollutants (POP)	ng i-Teq	11	2	**13**	**1**	**0**	1	0	**0**	**15**
19	Heavy Metals	mg Ni eq.	72	5	**77**	**13**	**1**	8	2	**5**	**96**
	PAHs	mg Ni eq.	79	1	**80**	**16**	**1**	0	2	**-2**	**95**
20	Particulate Matter (PM, dust)	g	25	6	**31**	**1026**	**0**	37	1	**36**	**1093**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	565	0	**565**	**0**	**6**	2	11	**-8**	**563**
22	Eutrophication	g PO4	4	0	**4**	**0**	**0**	0	0	**0**	**4**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

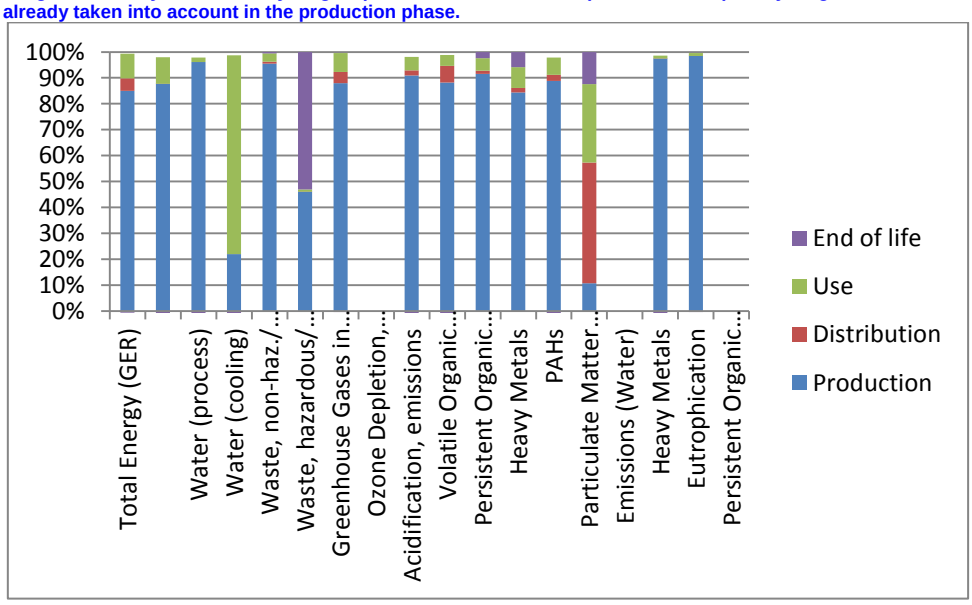


Figure 5.24: Basecase 13 ,Soft Starter, small: Breakdown of environmental impact, by type and life cycle phase.

6.2.14 Basecase 14 Soft Starter, Medium 11kW

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manu f.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**1650**			1485	165	**1650**	**0**
2	TecPlastics	g			**0**			0	0	**0**	**0**
3	Ferro	g			**0**			0	0	**0**	**0**
4	Non-ferro	g			**5500**			275	5225	**5500**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**2475**			1238	1238	**2475**	**0**
7	Misc.	g			**0**			0	0	**0**	**0**
	Total weight	g			**9625**			2998	6628	**9625**	**0**
									see note!		
	Other Resources & Waste							debit	credit		
8	Total Energy (GER)	MJ	7691	485	**8176**	**459**	**919**	217	278	**-61**	**9492**
9	of which, electricity (in primary PJ)	MJ	6071	105	**6177**	**1**	**718**	0	144	**-144**	**6751**
10	Water (process)	ltr	5731	31	**5761**	**0**	**101**	0	130	**-130**	**5733**
11	Water (cooling)	ltr	372	131	**503**	**0**	**1755**	0	30	**-30**	**2229**
12	Waste, non-haz./ landfill	g	30464	984	**31448**	**248**	**1075**	591	418	**172**	**32944**
13	Waste, hazardous/ incinerated	g	2205	11	**2216**	**5**	**37**	2723	162	**2561**	**4819**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.									
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	3740	162	**3902**	**86**	**222**	32	116	**-84**	**4126**
17	Volatile Organic Compounds (VOC)	g	77	8	**85**	**6**	**4**	1	2	**-1**	**94**
18	Persistent Organic Pollutants (POP)	ng i-Teq	85	15	**100**	**1**	**5**	4	2	**3**	**109**
19	Heavy Metals	mg Ni eq.	553	37	**590**	**13**	**56**	59	18	**41**	**699**
	PAHs	mg Ni eq.	610	6	**617**	**16**	**46**	0	15	**-15**	**664**
20	Particulate Matter (PM, dust)	g	193	43	**237**	**1026**	**667**	278	6	**273**	**2203**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	4346	1	**4348**	**0**	**48**	18	82	**-64**	**4331**
22	Eutrophication	g PO4	29	2	**31**	**0**	**0**	1	1	**0**	**31**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

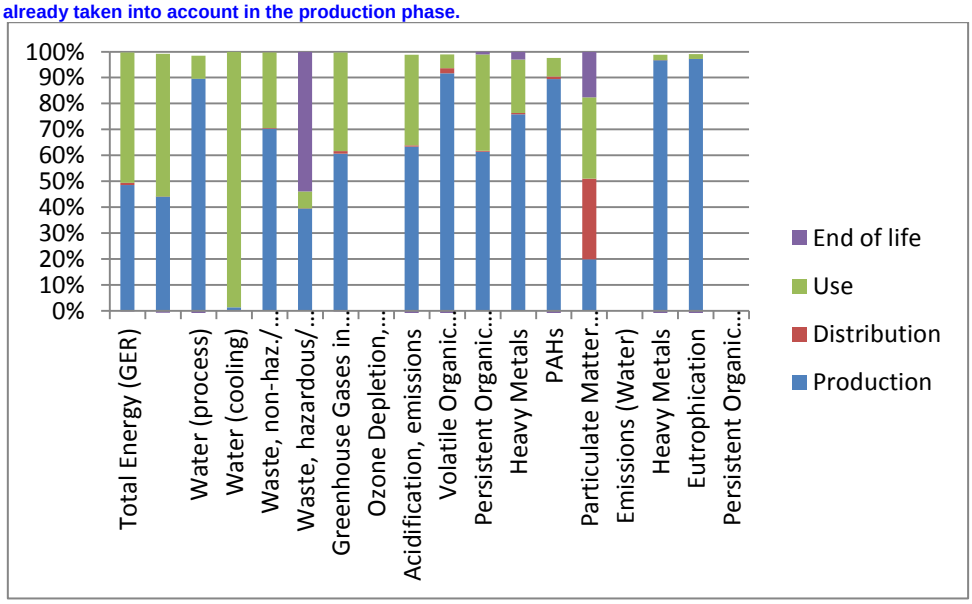


Figure 5.25: Basecase 14, Soft Starter, medium: Breakdown of environmental impact, by type and life cycle phase.

6.2.15 Basecase 15 Soft Starter Large 110kW

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**2750**			2475	275	**2750**	**0**
2	TecPlastics	g			**0**			0	0	**0**	**0**
3	Ferro	g			**0**			0	0	**0**	**0**
4	Non-ferro	g			**12100**			605	11495	**12100**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**6600**			3300	3300	**6600**	**0**
7	Misc.	g			**0**			0	0	**0**	**0**
	Total weight	g			**21450**			6380	15070	**21450**	**0**
									see note!		
	Other Resources & Waste							debit	credit		
8	Total Energy (GER)	MJ	24688	1180	**25868**	**459**	**26749**	464	656	**-192**	**52884**
9	of which, electricity (in primary PJ)	MJ	20897	214	**21111**	**1**	**26461**	0	383	**-383**	**47190**
10	Water (process)	ltr	19660	80	**19740**	**0**	**1947**	0	346	**-346**	**21341**
11	Water (cooling)	ltr	641	320	**961**	**0**	**70010**	0	75	**-75**	**70895**
12	Waste, non-haz./ landfill	g	72626	2175	**74801**	**248**	**31183**	1316	1113	**203**	**106435**
13	Waste, hazardous/ incinerated	g	3878	28	**3907**	**5**	**644**	5775	431	**5344**	**9899**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.									
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	12103	405	**12508**	**86**	**6903**	69	301	**-232**	**19265**
17	Volatile Organic Compounds (VOC)	g	266	21	**286**	**6**	**17**	1	4	**-3**	**306**
18	Persistent Organic Pollutants (POP)	ng i-Teq	255	33	**288**	**1**	**175**	9	4	**5**	**470**
19	Heavy Metals	mg Ni eq.	1831	82	**1913**	**13**	**521**	126	48	**77**	**2525**
	PAHs	mg Ni eq.	1461	17	**1478**	**16**	**118**	0	40	**-40**	**1572**
20	Particulate Matter (PM, dust)	g	541	112	**652**	**1026**	**1033**	593	15	**578**	**3289**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	14934	3	**14937**	**0**	**319**	39	220	**-181**	**15075**
22	Eutrophication	g PO4	91	5	**95**	**0**	**2**	2	3	**-1**	**96**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

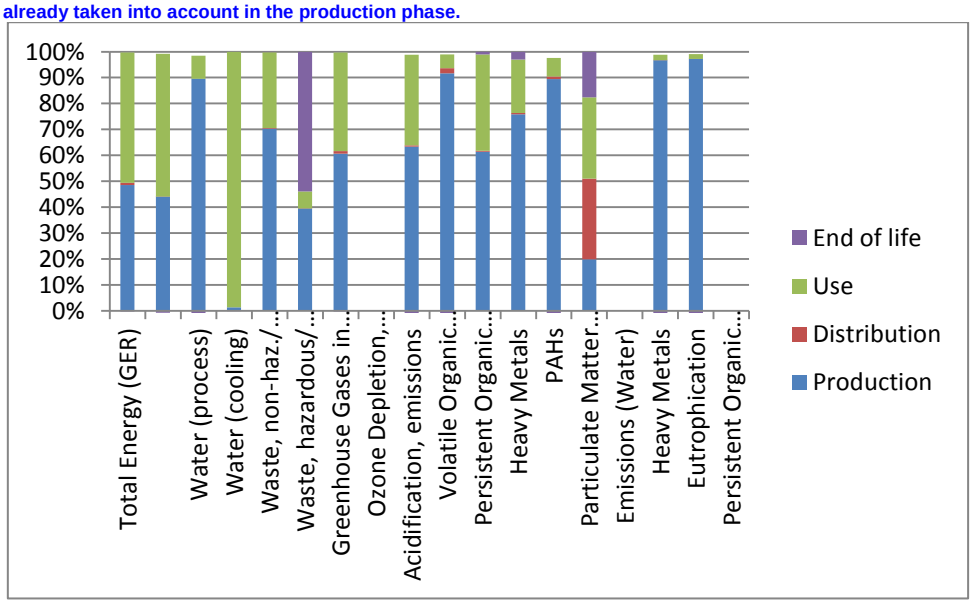


Figure 5.26: Basecase 15, Soft Starter, large: Breakdown of environmental impact, by type and life cycle phase.

6.2.16 Basecase 16 Submersible borehole pump motor Small 2.2kW

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manu f.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**660**			594	66	**660**	**0**
3	Ferro	g			**28952**			1448	27504	**28952**	**0**
4	Non-ferro	g			**9636**			482	9154	**9636**	**0**
5	Coating	g			**220**			11	209	**220**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**2310**			116	2195	**2310**	**0**
	Total weight	g			**41778**			2650	39128	**41778**	**0**
									see note!		
	Other Resources & Waste							debit	credit		
8	Total Energy (GER)	MJ	1657	69	**1726**	**92**	**61909**	183	67	**116**	**63843**
9	of which, electricity (in primary PJ)	MJ	142	42	**184**	**0**	**61412**	0	0	**0**	**61596**
10	Water (process)	ltr	40	1	**41**	**0**	**4094**	0	0	**0**	**4135**
11	Water (cooling)	ltr	358	20	**378**	**0**	**163764**	0	1	**-1**	**164141**
12	Waste, non-haz./ landfill	g	124146	217	**124364**	**71**	**72445**	2561	1	**2560**	**199440**
13	Waste, hazardous/ incinerated	g	21	0	**21**	**1**	**1415**	594	0	**594**	**2032**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	101	4	**105**	**7**	**2718**	14	5	**9**	**2839**
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	1731	17	**1747**	**19**	**15868**	27	6	**21**	**17655**
17	Volatile Organic Compounds (VOC)	g	4	0	**4**	**1**	**31**	1	0	**1**	**36**
18	Persistent Organic Pollutants (POP)	ng i-Teq	491	0	**491**	**0**	**407**	18	0	**18**	**916**
19	Heavy Metals	mg Ni eq.	357	0	**357**	**4**	**1161**	53	0	**53**	**1574**
	PAHs	mg Ni eq.	111	0	**111**	**4**	**226**	0	0	**0**	**341**
20	Particulate Matter (PM, dust)	g	148	3	**150**	**103**	**2103**	238	0	**238**	**2594**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	104	0	**104**	**0**	**397**	15	0	**15**	**517**
22	Eutrophication	g PO4	11	0	**11**	**0**	**2**	1	0	**1**	**13**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

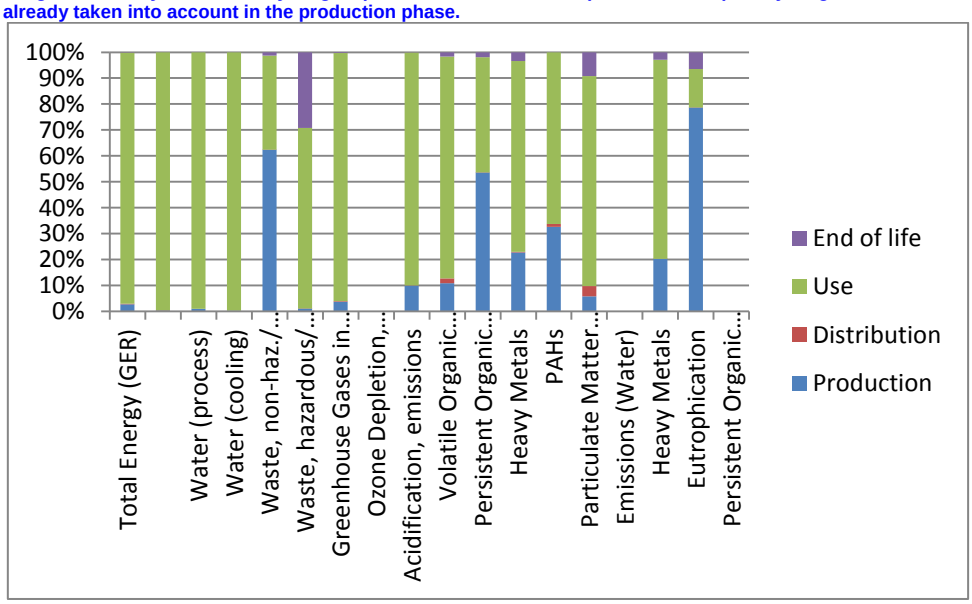


Figure 5.27: Basecase 16, Submersible borehole motor - Small: Breakdown of environmental impact, by type and life cycle phase.

6.2.17 Basecase 17 Submersible borehole pump motor Large 37kW

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	**Total**	**BUTION**		Disposal	Recycl.	**Total**	
	Materials	**unit**									
1	Bulk Plastics	g			**0**			0	0	**0**	**0**
2	TecPlastics	g			**1850**			1665	185	**1850**	**0**
3	Ferro	g			**287490**			14375	273116	**287490**	**0**
4	Non-ferro	g			**35150**			1758	33393	**35150**	**0**
5	Coating	g			**370**			19	352	**370**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**18870**			944	17927	**18870**	**0**
	Total weight	g			**343730**			18759	324971	**343730**	**0**
									see note!		
	Other Resources & Waste							debit	credit		
8	Total Energy (GER)	MJ	9238	379	**9617**	**323**	**2525622**	1287	335	**952**	**2536514**
9	of which, electricity (in primary PJ)	MJ	928	228	**1156**	**1**	**2525056**	0	1	**-1**	**2526212**
10	Water (process)	ltr	319	3	**323**	**0**	**168340**	0	0	**0**	**168662**
11	Water (cooling)	ltr	1259	108	**1366**	**0**	**6733466**	0	4	**-4**	**6734829**
12	Waste, non-haz./ landfill	g	704212	1189	**705401**	**182**	**2934700**	21070	3	**21067**	**3661351**
13	Waste, hazardous/ incinerated	g	64	0	**64**	**4**	**58185**	1665	0	**1665**	**59918**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	616	21	**637**	**21**	**110235**	96	25	**72**	**110964**
15	Ozone Depletion, emissions	mg R-11 eq.	negligible								
16	Acidification, emissions	g SO2 eq.	9131	91	**9222**	**61**	**650328**	189	31	**158**	**659769**
17	Volatile Organic Compounds (VOC)	g	35	0	**35**	**4**	**959**	5	0	**5**	**1003**
18	Persistent Organic Pollutants (POP)	ng i-Teq	3197	0	**3197**	**1**	**16583**	145	0	**145**	**19926**
19	Heavy Metals	mg Ni eq.	2149	0	**2149**	**9**	**43446**	374	0	**374**	**45978**
	PAHs	mg Ni eq.	314	0	**314**	**11**	**5082**	0	0	**0**	**5407**
20	Particulate Matter (PM, dust)	g	1881	14	**1895**	**684**	**15671**	1675	1	**1675**	**19924**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	605	0	**605**	**0**	**16287**	107	0	**107**	**17000**
22	Eutrophication	g PO4	37	0	**37**	**0**	**78**	6	0	**6**	**121**
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

***=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.**

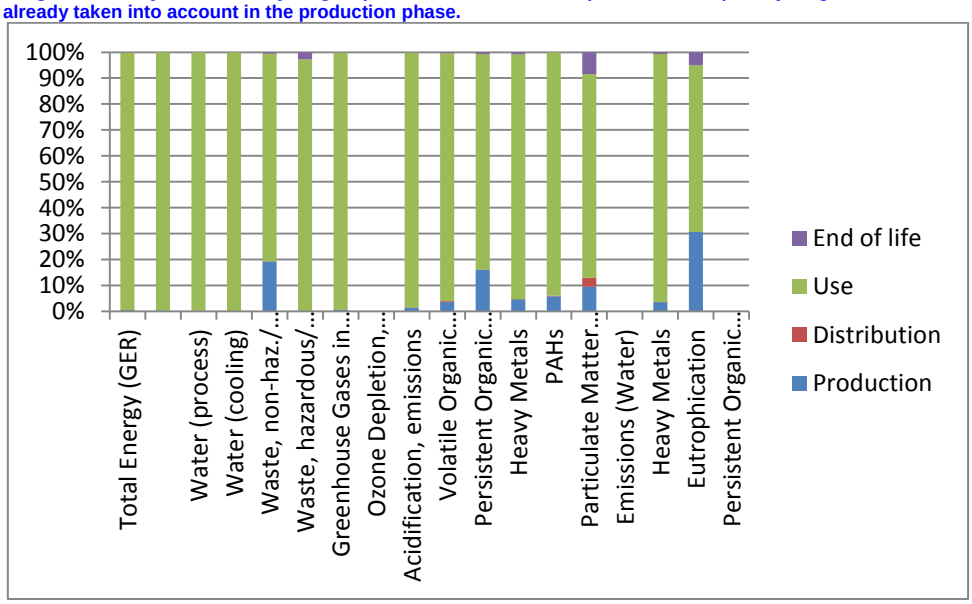


Figure 5.28: Basecase 17, Submersible borehole motor - Large: Breakdown of environmental impact, by type and life cycle phase.

6.2.18 Basecase 18 Motor + VSD Very Small 0.37kW

Nr	Life cycle Impact per product:	Date	Author
18	Motor + VSD - Very Small	V2.0 27 Nov 2013	HF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			148			133	15	148	0
2	TecPlastics	g			148			133	15	148	0
3	Ferro	g			6660			333	6327	6660	0
4	Non-ferro	g			3811			191	3620	3811	0
5	Coating	g			52			3	49	52	0
6	Electronics	g			216			108	108	216	0
7	Misc.	g			505			25	480	505	0
	Total weight	g			11540			926	10614	11540	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	1228	78	1306	208	10165	65	39	25	11704
9	of which, electricity (in primary MJ)	MJ	564	30	594	0	10158	0	13	-13	10740
10	Water (process)	ltr	510	3	513	0	682	0	11	-11	1184
11	Water (cooling)	ltr	114	21	135	0	27073	0	3	-3	27205
12	Waste, non-haz./ landfill	g	30907	232	31139	127	12082	707	37	671	44018
13	Waste, hazardous/ incinerated	g	198	1	198	3	236	375	14	360	797
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq	81	5	85	14	444	5	3	2	545
15	Ozone Depletion, emissions	mg R-11 e	negligible								
16	Acidification, emissions	g SO2 eq	729	23	752	40	2622	10	12	-2	3412
17	Volatile Organic Compounds (VOC)	g	8	1	8	2	4	0	0	0	15
18	Persistent Organic Pollutants (POP)	ng i-Teq	137	4	141	1	68	5	0	5	214
19	Heavy Metals	mg Ni eq	122	9	131	6	175	18	2	17	330
	PAHs	mg Ni eq	177	1	178	8	22	0	1	-1	206
20	Particulate Matter (PM, dust)	g	67	5	73	393	57	84	1	83	606
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	439	0	439	0	70	5	7	-2	507
22	Eutrophication	g PO4	5	0	5	0	0	0	0	0	6
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

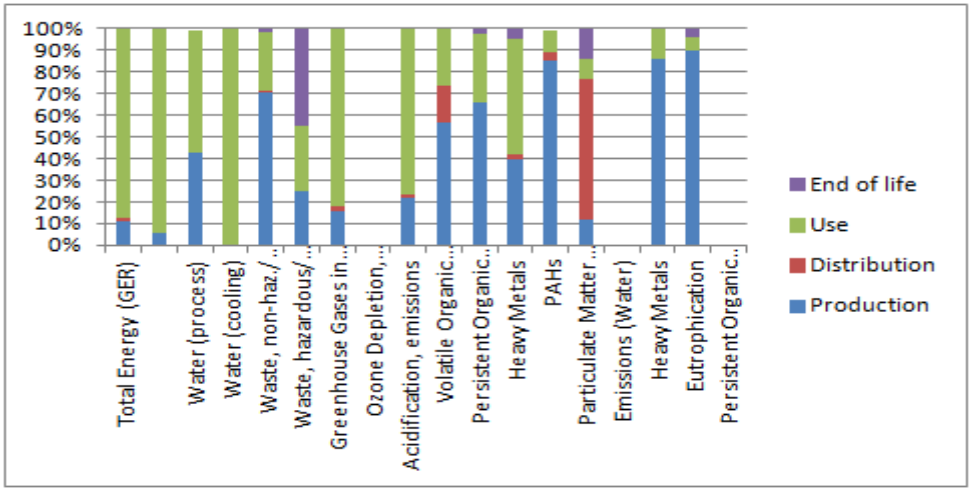


Figure 5.29: Basecase 18, Motor + VSD - Very Small: Breakdown of environmental impact, by type and life cycle phase.

6.2.19 Basecase 19 Motor + VSD Small 1.1kW

Nr	Life cycle Impact per product:	Date	Author
19	Motor + VSD - Small	V2.0 27 Nov 2013	HF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			330			297	33	330	0
2	TecPlastics	g			330			297	33	330	0
3	Ferro	g			17380			869	16511	17380	0
4	Non-ferro	g			9350			468	8883	9350	0
5	Coating	g			110			6	105	110	0
6	Electronics	g			495			248	248	495	0
7	Misc.	g			1155			58	1097	1155	0
	Total weight	g			29150			2241	26909	29150	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	2926	181	3107	350	26299	157	89	68	29824
9	of which, electricity (in primary MJ)	MJ	1299	70	1369	1	26282	0	29	-29	27622
10	Water (process)	ltr	1166	7	1173	0	1763	0	26	-26	2910
11	Water (cooling)	ltr	253	48	302	0	70051	0	7	-7	70345
12	Waste, non-haz./ landfill	g	80458	544	81001	195	31266	1787	84	1703	114165
13	Waste, hazardous/ incinerated	g	452	2	454	4	610	842	32	809	1877
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq	192	11	203	22	1148	12	6	6	1379
15	Ozone Depletion, emissions	mg R-11 e	negligible								
16	Acidification, emissions	g SO2 eq	1798	53	1851	66	6782	23	26	-3	8697
17	Volatile Organic Compounds (VOC)	g	18	2	20	5	10	1	0	0	35
18	Persistent Organic Pollutants (POP)	ng i-Teq	346	9	355	1	176	12	0	12	544
19	Heavy Metals	mg Ni eq	306	22	328	10	454	44	4	41	833
	PAHs	mg Ni eq	422	1	423	12	56	0	3	-3	489
20	Particulate Matter (PM, dust)	g	159	12	171	752	146	203	1	202	1272
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	1015	0	1015	0	180	13	16	-3	1191
22	Eutrophication	g PO4	11	0	12	0	1	1	0	1	13
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

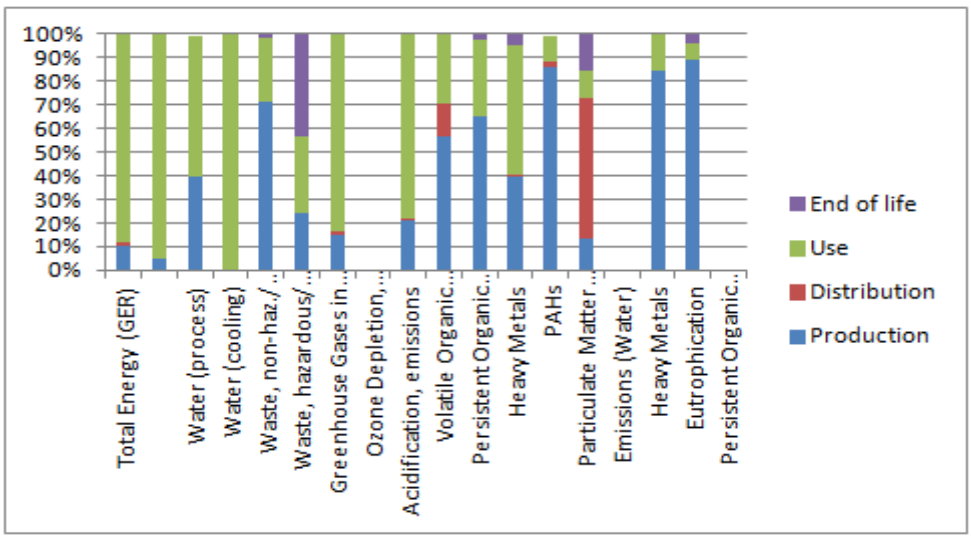


Figure 5.30: Motor + VSD - Small: Breakdown of environmental impact, by type and life cycle phase.

6.2.20 Basecase 20 Motor + VSD Medium 11kW

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			550			495	55	550	0
2	TecPlastics	g			1100			990	110	1100	0
3	Ferro	g			108130			5407	102724	108130	0
4	Non-ferro	g			41140			2057	39083	41140	0
5	Coating	g			550			28	523	550	0
6	Electronics	g			1320			660	660	1320	0
7	Misc.	g			10120			506	9614	10120	0
	Total weight	g			162910			10142	152768	162910	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	12164	629	12793	934	109209	702	332	370	123306
9	of which, electricity (in primary MJ)	MJ	4691	272	4964	2	108950	0	77	-77	113838
10	Water (process)	ltr	4053	19	4073	0	7301	0	69	-69	11304
11	Water (cooling)	ltr	814	165	979	0	290410	0	17	-17	291372
12	Waste, non-haz./ landfill	g	392321	2101	394422	477	130208	9986	224	9762	534869
13	Waste, hazardous/ incinerated	g	818	6	824	9	2518	2145	87	2059	5409
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq	795	37	833	57	4775	52	23	29	5693
15	Ozone Depletion, emissions	mg R-11 e	negligible								
16	Acidification, emissions	g SO2 eq	7557	177	7735	173	28133	103	79	24	36065
17	Volatile Organic Compounds (VOC)	g	68	4	73	14	45	3	1	1	132
18	Persistent Organic Pollutants (POP)	ng i-Teq	1861	40	1901	3	733	69	1	68	2704
19	Heavy Metals	mg Ni eq	1366	93	1460	24	1922	202	10	192	3598
	PAHs	mg Ni eq	1799	3	1802	31	272	0	8	-8	2097
20	Particulate Matter (PM, dust)	g	729	37	766	2223	1268	911	3	908	5165
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	3746	1	3747	1	740	58	44	14	4502
22	Eutrophication	g PO4	41	1	42	0	4	3	1	3	48
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

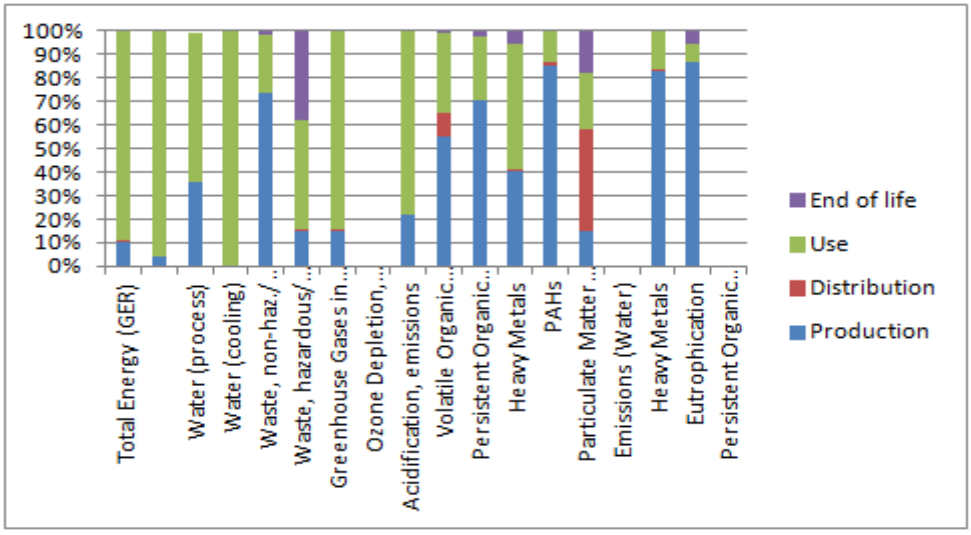


Figure 5.31: Motor + VSD - Medium: Breakdown of environmental impact, by type and life cycle phase.

6.2.21 Basecase 21 Motor + VSD Large 110kW

Nr	Life cycle Impact per product:	Date	Author
21	Motor + VSD - Large	V2.0 27 Nov 2013	HF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			3300			2970	330	3300	0
2	TecPlastics	g			5500			4950	550	5500	0
3	Ferro	g			950400			47520	902880	950400	0
4	Non-ferro	g			134200			6710	127490	134200	0
5	Coating	g			1100			55	1045	1100	0
6	Electronics	g			8800			4400	4400	8800	0
7	Misc.	g			56100			2805	53295	56100	0
	Total weight	g			1159400			69410	1089990	1159400	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	60788	2919	63707	4258	1519115	4796	1832	2964	1590044
9	of which, electricity (in primary MJ)	MJ	26961	1088	28050	9	1518517	0	513	-513	1546063
10	Water (process)	ltr	23357	119	23476	0	101451	0	463	-463	124464
11	Water (cooling)	ltr	4553	798	5351	0	4048685	0	111	-111	4053925
12	Waste, non-haz./ landfill	g	2311138	7564	2318701	2080	1783497	71071	1491	69579	4173857
13	Waste, hazardous/ incinerated	g	3304	38	3341	41	35018	12320	576	11744	50144
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq	4220	175	4395	253	66318	358	128	230	71195
15	Ozone Depletion, emissions	mg R-11 e	negligible								
16	Acidification, emissions	g SO2 eq	42458	864	43322	778	391398	705	490	214	435712
17	Volatile Organic Compounds (VOC)	g	419	28	447	65	580	18	7	11	1103
18	Persistent Organic Pollutants (POP)	ng i-Teq	11057	78	11135	12	10063	489	6	484	21694
19	Heavy Metals	mg Ni eq	8772	188	8960	106	26189	1382	65	1318	36572
	PAHs	mg Ni eq	4468	23	4491	140	3088	0	53	-53	7665
20	Particulate Matter (PM, dust)	g	6628	199	6827	10599	9301	6227	22	6205	32932
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	19682	4	19686	3	9986	399	293	106	29781
22	Eutrophication	g PO4	214	7	221	0	49	23	4	19	289
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

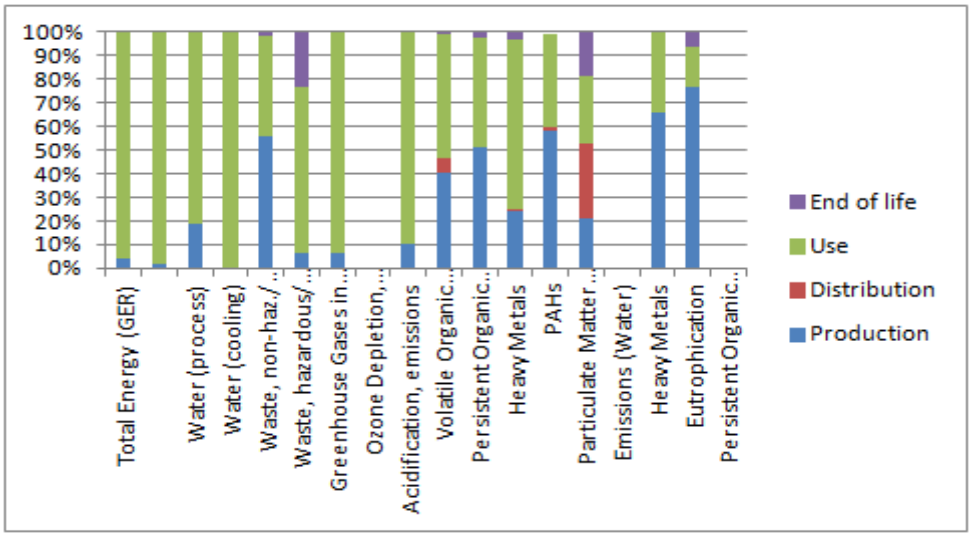


Figure 5.32: Motor + VSD - Large: Breakdown of environmental impact, by type and life cycle phase.

6.2.22 Basecase 22 Motor + VSD Very Large 550kW

Nr	Life cycle Impact per product:	Date	Author
22	Motor + VSD - Very Large	V2.0 27 Nov 2013	HF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			14850			13365	1485	14850	0
2	TecPlastics	g			13750			12375	1375	13750	0
3	Ferro	g			2249500			112475	2137025	2249500	0
4	Non-ferro	g			359900			17995	341905	359900	0
5	Coating	g			2750			138	2613	2750	0
6	Electronics	g			39600			19800	19800	39600	0
7	Misc.	g			140250			7013	133238	140250	0
	Total weight	g			2820600			183160	2637440	2820600	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	204474	10598	215072	11179	8494418	12719	6293	6426	8727095
9	of which, electricity (in primary MJ)	MJ	114467	3384	117851	23	8493205	0	2306	-2306	8608773
10	Water (process)	ltr	103173	514	103687	0	567172	0	2080	-2080	668779
11	Water (cooling)	ltr	12911	2891	15803	0	22645562	0	478	-478	22660886
12	Waste, non-haz./ landfill	g	5049145	25236	5074381	5416	9896767	172904	6694	166210	15142774
13	Waste, hazardous/ incinerated	g	14450	169	14619	108	195827	45540	2590	42950	253503
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq	14452	647	15099	661	370757	949	435	514	387030
15	Ozone Depletion, emissions	mg R-11 e	negligible								
16	Acidification, emissions	g SO2 eq.	121613	3277	124890	2037	2187964	1871	2026	-154	2314737
17	Volatile Organic Compounds (VOC)	g	1639	126	1764	171	3220	47	30	17	5172
18	Persistent Organic Pollutants (POP)	ng i-Teq	27844	286	28130	31	55943	1191	25	1166	85270
19	Heavy Metals	mg Ni eq	23426	696	24122	275	145984	3644	291	3353	173735
	PAHs	mg Ni eq	16251	103	16353	366	16945	0	240	-240	33425
20	Particulate Matter (PM, dust)	g	17598	801	18399	28037	47772	16490	95	16396	110603
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	83584	17	83601	9	55590	1059	1320	-261	138939
22	Eutrophication	g PO4	725	31	756	0	269	61	19	42	1067
23	Persistent Organic Pollutants (POP)	ng i-Teq	negligible								

*=Note: Recycling credits only relate to recycling of plastics and electronics (excl. LCD/CRT). Recycling credits for metals and other fractions are already taken into account in the production phase.

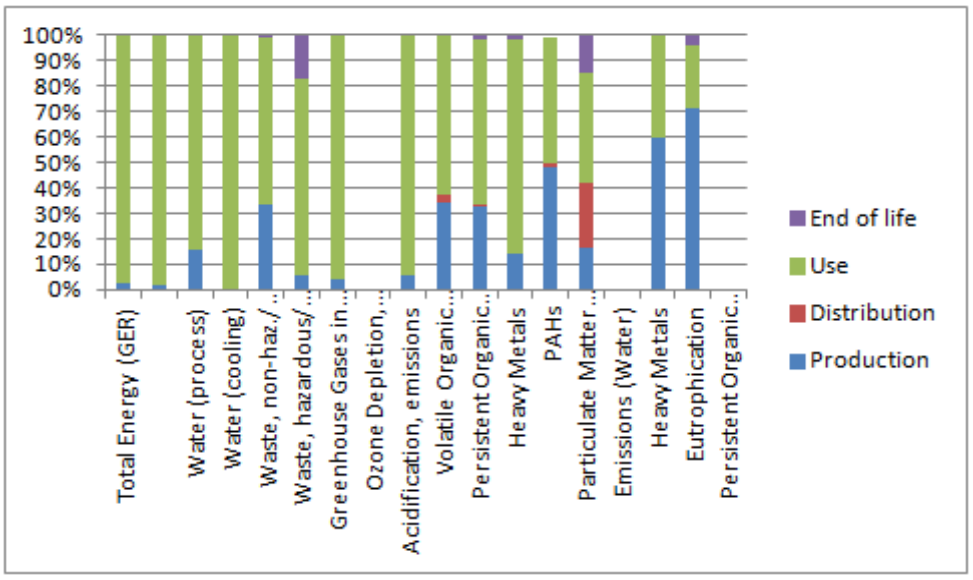


Figure 5.33: Motor + VSD – Very Large: Breakdown of environmental impact, by type and life cycle phase.

6.3 Conclusions

This Task 5 basecase environmental analysis gives the reference point about which subsequent comparisons of improved technologies (BAT and BNAT) are made (Task 7).

For all types of motor, the energy consumption (in use phase) dominates in almost all types of environmental impact. **This indicates that reducing the energy consumption should be the priority option for reducing the environmental impact of motors.**

The total environmental impact of VSDs is considerably less than that of motors, partly because they are inherently efficient at mid to high load, and because they will not be used on all motor systems. However, a watching brief should be maintained in order to identify any cost effective technologies that might be capable of reducing their losses, especially as the total stock is anticipated to keep increasing.

The environmental impact of soft starters is extremely small, as normally they are only actually energized for a short time during motor switch on and switch off. Even during these periods the losses are quite small. Because of this, they are not analysed any further in this study.

The distinction between motor energy consumption and losses is important, as motors are almost unique in EUP studies in that most of the energy consumed is used to drive another product – it is only the internal losses that are of concern.

The need to adequately present the benefits of VSDs has led to the introduction of an additional basecase of Motor + VSD, which assesses the performance of the combined product as a whole. This means that new technology products using alternatives to the induction motor can be compared on an equal basis. In addition, the analysis in this study includes an estimation of the increase in motor losses when used with a VSD. This will ensure that when other drive products are compared in Task 7, they can be compared on a total losses basis.

Because Permanent Magnet, Synchronous Reluctance and other new technologies are considered to be improvements on the conventional motors considered here, they do not have a separate basecase, and instead will be part of the Task 7 analysis.

For both soft starters and VSDs, it is possible that some products have significantly lower standby power consumption than others, but this is something on which there has been no data. The breakdown of standby energy consumption is complicated by the many variations in communications, display and ancillaries, and so is not attempt to assess this has been made.