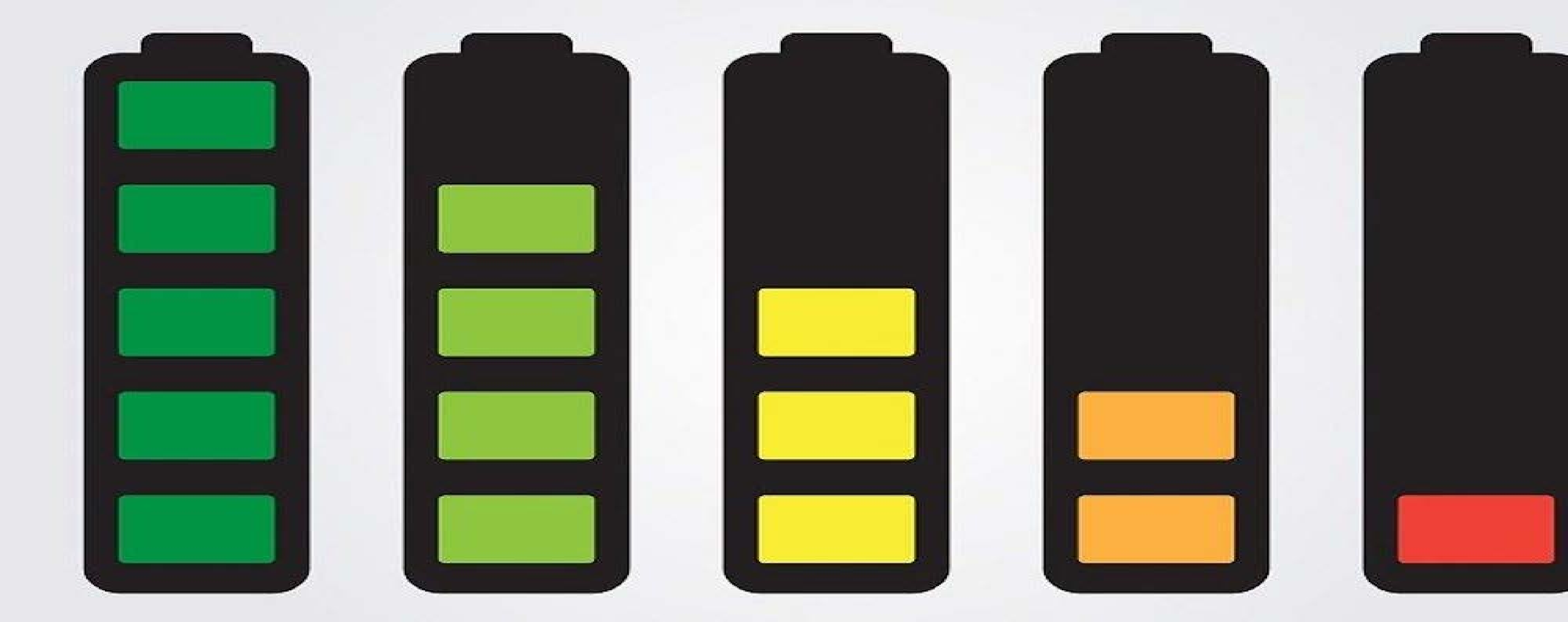

ECODESIGN BATTERIES – 2ND STAKEHOLDER MEETING
PRESENTATION OF TASK 6 (WITHOUT LCA PART)

Tim Hettesheimer, Antoine Durand

May 2nd, 2019 – Albert Borschette Centre - Brussels

TASK 6: DESIGN OPTIONS

Objective of task 6

- Task 6 relies on input from Tasks 4 and 5

- The **aim of task 6** is to:
  - identify design options,
  - identify corresponding monetary consequences in terms of Life Cycle Cost for the user,
  - outline the solution with the Least Life Cycle Costs (LLCC) and the Best Available Technology (BAT).

- **This part of task 6 presentation focuses on**:
  1) Identification of design options
  2) Description of the design options and
  3) Description of the influence on the performance indicators
  4) Discussion of possible rebound effects
  5) Final remarks

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1) TASK 6: DESIGN OPTIONS

Design options to be considered in task 6

1. **Design option 1: Enable a higher energy density for batteries**
   - Considers an increased energy density of the cells, packs or system due to a change in cell chemistries and reduction of passive materials (see task 4 report).
   - Thus, design option's major impact is on side of materials (BOM).

2. **Design option 2: Extended lifetime**
   - Considers the opportunity to prolong the product's lifetime due to 2^{nd} life application and thus to increase the QFU.
   - This design option mainly aims on the performance indicators

3. **Design option 3: Low carbon energy mix for the production of the battery**
   - Addresses the issue that the environmental impact of the production phase is comparatively high (in comparison to the use phase) and that it is mainly influenced by the used energy mix.
   - Has no direct influence on the materials (BOM) or the performance indicators but contributes highly to GWP of the product.

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2) TASK 6: SUBTASK 6.1 - DESCRIPTION OF DESIGN OPTIONS

1. Enable a higher energy density for batteries

Description of design option:

- As described in task 4 a higher energy density of the battery cell, module or system can be achieved for example by using improved cell materials, reducing the amount or weight of passive materials, optimizing the design etc..
- **The aim of this report is not to describe and analyse the potential environmental impact of every single improvement option listed in task 4** (which be limited by data availability), but rather to assess if improving the energy density has a positive influence on the environmental impact at all.
- **Positive effect may for example result from lower amount of materials** needed to provide the same service.

2) TASK 6: SUBTASK 6.1 - DESCRIPTION OF DESIGN OPTIONS

1. *Enable a higher energy density for batteries*

„New“ cells (task 6)

		Improved (NMC) Pouch cell	Improved PHEV Pouch cell	Improved (Blended) Prismatic cell	Improved (NCA) Cylindrical cell	Improved (LFP) Prismatic cell
General Information	Format	Pouch	Pouch	Prismatic	Cylindrical	Prismatic
	Chemistry	NCM 811	NCM 622	NCM622/NCA(80/15/5)/LMO - 6/2/2	NCA (92/5/3) - Gr/Si	LFMP
	Ah		32	94	4,75	250
	Wh	220,00	126	347,8	17,1	875
	V	3,60	3,7	3,7	3,6	3,5
	W/mm		171	173	21,3	410
	H/mm		233	125	70,3	146
	T/mm		7,5	45	21,3	58

„Old“ cells (task 4)

		NMC Pouch cell (form GREET Model)	LGC Volt (Gen2)	SDI BMW i3	Panasonic 18650	BYD 200Ah for e6/k9
General Information	Format	Pouch	Pouch	Prismatic	Cylindrical	Prismatic
	Chem.	NCM 622	NCM424/NCM111	NCM523/NCA(80/	NCA (82/15/3)	LFP
	Ah	59	25,9	60	3,18	200
	Wh	212	96	222	11,45	640
	V	3,6	3,7	3,7	3,6	3,2
	W/mm		171	173	18,25	410
	H/mm		233	125	65,1	146
	T/mm		7,5	45	18,25	58

BOM Cell level		Material	Amount per Wh in g	Amount per Wh in g	Amount per Wh in g	Amount per Wh in g	Amount per Wh in g
Cathode	Cathode active material						
	Cathode active material 1	Fe					
	Cathode active material 2	Co					
	Cathode active material 3	Ni					
	Total cathode		0,00	1,87	1,97	1,46	2,61
Anode	Anode active material	Graphite	0,98	0,95	0,98	0,93	1,14
	Anode binder 1	SBR	0,00	0,04	0,02	0,01	0,03
	Anode binder 2	CMC	0,00	0,00	0,02	0,01	0,03
	Anode collector	Cu foil	0,75	0,42	0,47	0,26	0,73
	Anode heatresistnt layer	Al	0,00	0,00	0,05	0,00	0,00
	Total anode		0,00	1,41	1,54	1,21	1,94
Electrolyte	Formulated electrolyte		0,00	0,61	0,86	0,40	1,26
	Fluid	LiPF6	0,12	0,08	0,11	0,05	0,16
	Fluid	LiFSI	0,00	0,00	0,00	0,00	0,00
	Solvents	EC	0,34	0,20	0,28	0,13	0,40
	Solvents	DMC	0,34	0,20	0,28	0,13	0,40
	Solvents	EMC	0,00	0,14	0,20	0,09	0,29
	Solvents	PC	0,00	0,00	0,00	0,00	0,00
	Total electrolyte		0,00	0,61	0,86	0,40	1,25
Separator	Separator	PE 10 micron+AL2O3	0,02	0,00	0,00	0,00	0,00
	Separator	PP 15 micron + AL2O	0,07	0,14	0,00	0,00	0,00
	Separator	PP/PE/PP	0,00	0,00	0,13	0,00	0,25
	Separator	PE-Al2O3	0,00	0,00	0,00	0,09	0,00
	Total separator		0,00	0,14	0,13	0,09	0,25
Cell Packaging	Tab with film	Al Tab	0,00	0,04	0,00	0,00	0,00
		Ni Tab	0,00	0,13	0,00	0,00	0,00
	Exterior covering	PET/Ny/Al/PP/ Lamin	0,01	0,15	0,00	0,00	0,00
	Collector parts	Al leads	0,00	0,00	0,01	0,00	0,02
	Collector parts	Cu leads	0,00	0,00	0,03	0,00	0,05
	Collector parts	Plastic fasteners/cove	0,00	0,00	0,05	0,00	0,02
	Cover	Valve, rivet terminals,	0,00	0,00	0,29	0,12	0,11
	Case	Al	0,00	0,00	0,35	0,00	0,91
	Case	Ni plating Iron	0,00	0,00	0,00	0,44	0,00
	Total cell packaging		0,01	0,32	0,72	0,56	1,12

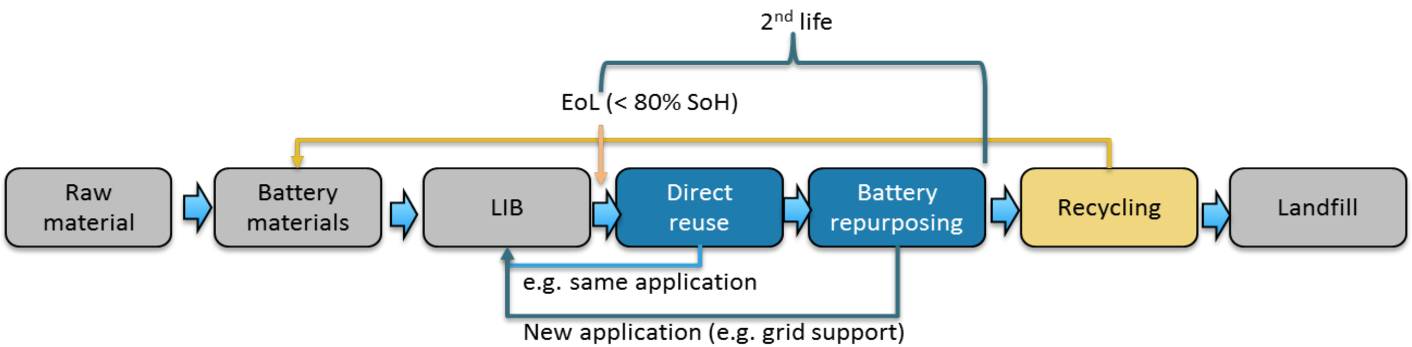
Approach

- BOM for different industrial battery cells as depicted in task 4 is updated based on “improved” cell generations.
- Based on these five different cells, a virtual product is calculated again (calculation is following the same way as described in task 4).
- For the virtual product the BOM is determined and used to calculate the environmental impact.

➢ Approach allows to analyse the influence of improved cell materials and the reduction of passive materials based on the same/similar cell design as used before.

2. *Extended lifetime*

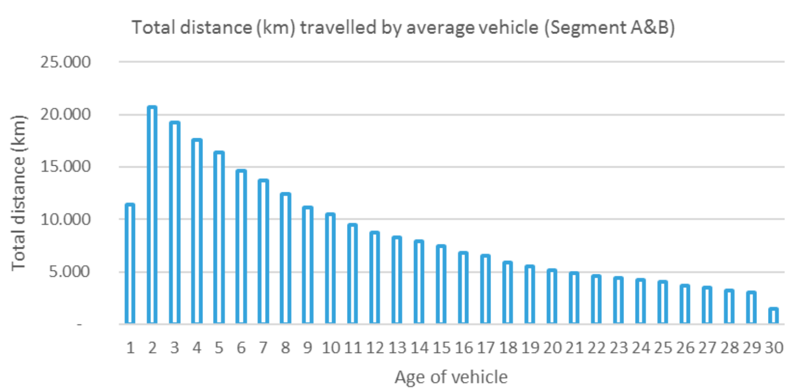
- 2nd life application offers the possibility to prolong the service life of a product and thus enables it to increase the QFU (Quantify of Functional Unit).
- Different possibilities for 2nd life applications such as **repurposing and reuse**. Out of the environmental impact perspective **both options are going into the same direction**. Although, in the first case, the effort is a bit higher since some additional components may have to be changed.
- Here again, it is **not the aim to conduct an in-depth analyses of the environmental impact of different 2nd life options** but rather to **assess the general potential of such a prolonged product lifetime**.
- ➢ For this reason, this report focusses exemplarily on the effect of **an extended lifetime due to battery reuse**. Therefore, it is assumed that a battery, which reaches the end of its 1st life (mostly at 70 % to 80 % SOH) is reused in the same application (e.g. in a smaller city car).



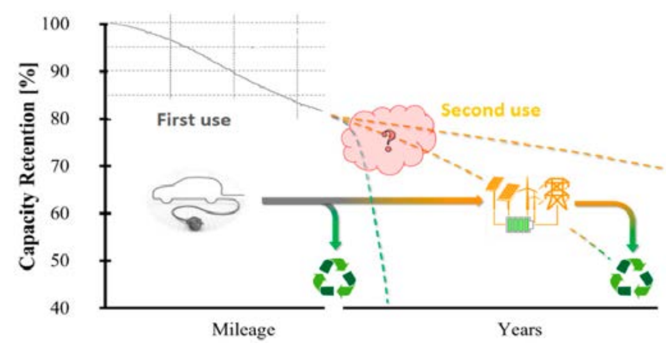
End-of-life options for LiB (based on European Environment Agency 2018)

2. *Extended lifetime*

- The figure below illustrates, that the older a car is, the less it is driven. Thus it would also make economically less sense to install a new battery system, since a reused battery would also be sufficient for only a part of the costs.
- the **remaining capacity might still be sufficient** to fulfil the expected service of the vehicle.
- Considered **prolonged lifetime of battery for a PC BEV** (and Truck BEV). For the PHEV versions the end-of-first life was assumed at ~ 60% SOH. Due to this low SOH a further reuse seems not applicable. For the stationary systems, the reuse of batteries in other systems might be thinkable but is not further investigated here.
- For the PC BEV it is assumed, that after the battery reaches its end of first life, the **battery is reused until it reaches ~ 60% SOH**. Afterwards, the battery is disposed.



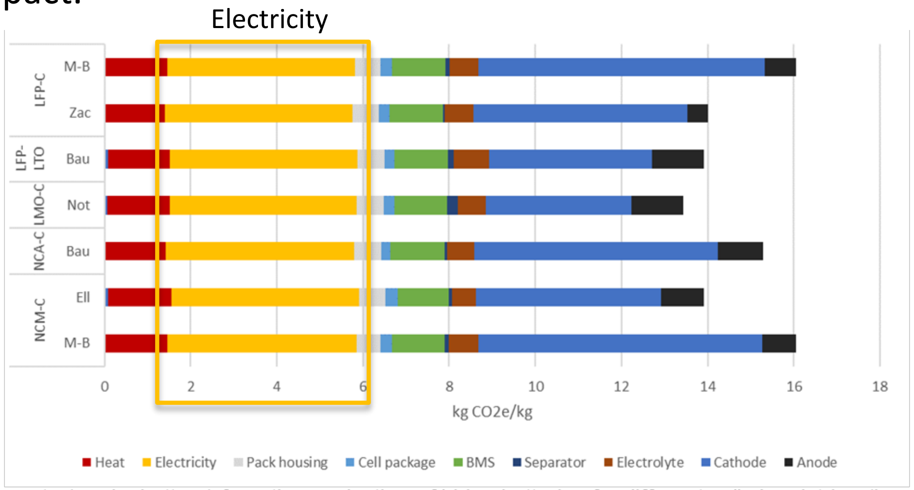
Average annual driven kilometres of a small car in the EU (Papadimitriou 2013)



Options after the first-life of the battery (Podias et al. 2018)

3. Low carbon energy mix for the production of the battery

- The analyses in task 4 regarding the most relevant contributors of GWP revealed that the **electricity consumption during the production process highly contributes to the overall greenhouse gas emissions.** The electricity consumption has next to the cathode materials the highest GWP impact.



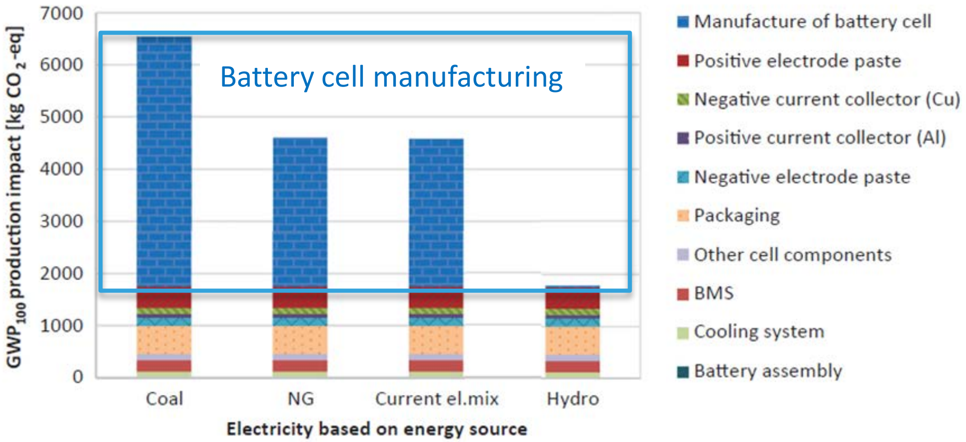
GWP impacts (per kg battery) from the production of Li-ion batteries for different cell chemistries (based on Hill et al. 2018)

- This is an issue that has been also observed by many other studies*. Furthermore those studies identified the electricity mix as the biggest lever for reducing the GWP.

*see for example Romare and Dahllöf 2017, Thomas et al. 2018; Ellingsen et al. 2014

3. *Low carbon energy mix for the production of the battery*

- The energy source used for the production of the battery, the GWP emissions differ significantly according to the energy source used. Ellingsen et al. 2014 provided a sensitivity analysis.



Influence of different energy sources on the GWP (based on Ellingsen et al. 2014)

➢ Thus, for this design option the impact of the usage of two different electricity mixes and their corresponding GHG emissions are calculated.
  - The first one is intended to reflect the current electricity mix. according to PRIMES, the electricity mix in the EU28 accounts currently for about 0.38 kg CO2eq/kWh.
  - However, depending on the technology, GHG emissions power generation can range between 1.284 kg CO2eq/kWh and 0.004 kg CO2eq/kWh. Based on these values, the resulting GHG emissions during the production are calculated.

3) SUBTASK 6.2: IMPACTS OF THE DESIGN OPTIONS ON PERFORMANCE INDICATORS

1. Design option "Higher energy density"

BaseCase		BC 1	BC 2	BC 3	BC 4	BC 5	BC6	BC7
Short Description		PC BEV HIGH	PC BEV LOW	PC PHEV	Truck BEV	Truck PHEV	Residential ESS	Commercial ESS
Main application		eMobility					stationary	
Parameter	unit	BC 1	BC 2	BC 3	BC 4	BC 5	BC6	BC7
Typical capacity of the application	[kWh]	80	40	12	360	160	10	30.000
Economic life time of application (Tapp)	[y]	13	14	13	14	12	20	20
Percent of braking energy recovery in AS	[-]	20%	20%	20%	12%	6%	n.a.	n.a.
Application service energy (AS)	[kWh/Tapp]	43.680	29.568	19.656	940.800	890.400	40.000	120.000.000
Charger Efficiency (ηcharger)	[-]	85%	85%	85%	92%	92%	98%	98%
Consumption	[kWh/km]	0,2	0,16	0,18	1,2	1,4	n.a.	n.a.
Annual kilometers	[km/a]	14000	11000	7000	50000	50000	n.a.	n.a.
C-rate for charging	[-]	0,5	0,5	0,5	1,0	1,0	0,5	1,0
C-rate for normal discharge	[-]	1,0	1,0	1,0	1,0	1,0	1,0	1,0
C-rate for braking	[-]	3,0	3,0	3,0	3,0	3,0	3,0	3,0
Nominal battery system capacity according to ISO ..	[kWh]	80	40	12	30	20	10	10
Number of battery systems per application	[-]	1	1	1	12	8	1	3.000
Maximum calendar life-time of the installed battery (no cycling ageing)	[year]	20	20	20	20	20	25	25
Maximum SoC - maximum DoD (Stroke)	[-]	80%	80%	75%	80%	75%	80%	80%
Average stroke (SoC - DoD)	[-]	24%	31%	73%	50%	69%	60%	75%
Energy delivered in first cycle (Edc).	[kWh/cycle]	64	32	9	24	15	8	8
Number of cycles per year (#)	cycles	120	120	120	300	600	250	250
Maximum number of cycles for battery system until EoL (no calendar ageing)	[-]	1.500	1.500	2.000	2.000	3.000	8.000	10.000
SoH @ EoL of battery system relative to declared capacity (SoHcap)	[-]	80%	80%	60%	80%	60%	70%	70%
Average energy delivered per average cycle until EoL	[kWh/cycle]	19,44	12,22	8,75	178,57	110,06	6,00	22.500,00
number of batteries in the application	[-]	1,00	1,00	1,00	12,00	8,00	1,00	3.000,00
Actual quantity of functional units (QFU) over battery system lifetime (per battery) *(1 FU = 1 kWh over battery lifetime).*	[-]	40.320	23.642	13.440	482.297	373.177	25.532	95.744.681
Service life of first battery (years)	[year]	14,40	13,43	10,67	8,04	5,33	17,02	17,02
Battery system costs	[€/kWh]	140	140	185	129	185	499	499
CAPEX for decomissioning	[EURO/ battery]	1.200	600	180	450	300	150	150
OPEX replace battery	[EURO/ battery]	700	700	700	400	400	100	100
ηcoul x ηv =average energy efficiency of battery system over life time	[-]	96%	96%	96%	96%	96%	96%	96%
Auxiliary heating energy for a battery system relative to functional unit	kW	5,0	5,0	-	5,0	-	-	-
Self discharge per month(@STC)	[-]	2%	2%	2%	2%	2%	2%	2%
Total weight of a battery	[kg]	521	261	98	221	163	101	101
Total weight of cells	[kg]	391	195	68	166	114	66	66
Specific energy density cell level	[Wh/kg]	205	205	176	181	176	152	152
Weight of Cobalt	[kg]	5	3	1	1	1	0	0
Weight of Graphite	[kg]	79	40	13	31	21	11	11
Weight of Nickel	[kg]	44	22	4	12	6	1	1
Weight of Manganese	[kg]	12	6	4	7	6	4	4
Weight of Lithium	[kg]	13,9	7,0	1,7	4,5	2,8	1,0	1,0

- Subtask analyses the **influence of the design options on the performance indicators** and the **BOM**

- This First design option aims at the reduction and substitution of materials and thus focusses on the EI due to the BOM.
- Furthermore, the use of such materials as well as the reduction of passive materials also leads to a reduction in the costs per kWh as listed in the line named "Battery systems costs".
- Performance indicators are quite similar to those of the BAU of the Base Cases.

3) SUBTASK 6.2: IMPACTS OF THE DESIGN OPTIONS ON PERFORMANCE INDICATORS

2. Design option "Extended lifetime"

BaseCase		BC 1	BC 2	BC 3	BC 4	BC 5	BC6	BC7
Long Description		Passenger Car - BEV high battery capacity	Passenger Car - BEV lower battery capacity	Passenger Car PHEV	Truck BEV	Truck PHEV	Residential ESS	Grid supporting ESS
Main application		eMobility					stationary	
Parameter	unit	BC 1	BC 2	BC 3	BC 4	BC 5	BC6	BC7
Typical capacity of the application	[kWh]	80	40	12	360	160	10	30.000
Economic life time of application (Tapp)	[y]	13	14	13	14	12	20	20
Percent of braking energy recovery in AS	[-]	20%	20%	20%	12%	6%	n.a.	n.a.
Application service energy (AS)	[kWh/Tapp]	43.680	29.568	19.656	940.800	890.400	40.000	120.000.000
Charger Efficiency (ηcharger)	[-]	85%	85%	85%	92%	92%	98%	98%
Consumption	[kWh/km]	0,2	0,16	0,18	1,2	1,4	n.a.	n.a.
Annual kilometers	[km/a]	14000	11000	7000	50000	50000	n.a.	n.a.
C-rate for charging	[-]	0,5	0,5	0,5	1,0	1,0	0,5	1,0
C-rate for normal discharge	[-]	1,0	1,0	1,0	1,0	1,0	1,0	1,0
C-rate for braking	[-]	3,0	3,0	3,0	3,0	3,0	3,0	3,0
Nominal battery system capacity according to ISO ..	[kWh]	80	40	12	30	20	10	10
Maximum calendar life-time of the installed battery (no cycling ageing)	[year]	20	20	20	20	20	25	25
Maximum SoC - maximum DoD (Stroke)	[-]	80%	80%	75%	80%	75%	80%	80%
Average stroke (SoC - DoD)	[-]	24%	31%	73%	50%	69%	60%	75%
Energy delivered in first cycle (Edc).	[kWh/cycle]	64	32	9	24	15	8	8
Number of average cycles per year (#)	cycles	120	120	120	300	600	250	250
Maximum number of full cycle equivalents for battery system until EoL (no calendar ageing)	[-]	1.500	1.500	2.000	2.000	3.000	8.000	10.000
SoH @ EoL of battery system relative to declared capacity (SoHcap)	[-]	80%	80%	60%	80%	60%	70%	70%
Average energy delivered per average cycle until EoL	[kWh/cycle]	19,44	12,22	8,75	178,57	110,06	6,00	22.500,00
number of batteries in the application	[-]	1,00	1,00	1,00	12,00	8,00	1,00	3.000,00
Actual quantity of functional units (QFU) over battery system lifetime (per battery) *(1 FU = 1 kWh over battery lifetime).*	[-]	40.320	23.642	13.440	482.297	373.177	25.532	95.744.681
Service life of first battery (years)	[year]	14,40	13,43	10,67	8,04	5,33	17,02	17,02
Prolonged lifetime due to Reuse (quadratic aging)	[y]	3,60	3,36	0,00	2,01	0,00	2,43	2,43
Load level as compared to first life (e.g. lower maximum energy per cycle)	[%]	70%	70%	70%	70%	70%	70%	70%
Average SoH during Reuse-phase	[%]	0,70	0,70	0,00	0,70	0,00	0,65	0,65
SoH @ EoL of re-use-phase	[%]	0,60	0,60	0,60	0,60	0,60	0,60	0,60
Maximum energy deliverable per cycle @ Reuse phase	[kWh/cycle]	56,00	28,00	0,00	252,00	0,00	6,50	19.500,00
Average energy delivered per cycle @ Reuse phase	[kWh/cycle]	13,61	8,56	0,00	125,00	0,00	4,20	15.750,00
Maximum additional FU due to Reuse	[-]	19.353,60	9.026,87	0,00	121.538,76	0,00	3.404,26	10.212.765,96
Actual additional FU due to Reuse	[-]	5.880,00	3.447,76	0,00	75.358,85	0,00	2.553,19	9.574.468,09
Actual QFU including first use and re-use of battery	[-]	46.200	27.090	13.440	557.656	373.177	28.085	95.744.681
Battery system cost/declared initial capacity	[EURO/kWh]	206	206	254	220	212	683	683
CAPEX for decomissioning	[EURO/battery]	1.200	600	180	450	300	150	150
OPEX replace battery	[EURO/battery]	840	840	840	480	480	120	120
ηcoul x ηv =average energy efficiency of battery system over life time	[-]	96%	96%	96%	96%	96%	96%	96%
Auxiliary heating energy for a battery system relative to functional unit	kW	5,0	5,0	-	5,0	-	-	-
Self discharge per month(@STC)	[-]	2%	2%	2%	2%	2%	2%	2%
Total weight of a battery	[kg]	609	304	126	256	210	128	128
Total weight of cells	[kg]	456	228	88	192	147	83	83
Specific energy density cell level	[Wh/kg]	175	175	136	156	136	120	120
Weight of Cobalt	[kg]	10	5	1	3	2	0	0
Weight of Graphite	[kg]	87	44	16	36	26	14	14
Weight of Nickel	[kg]	36	18	3	10	6	1	1
Weight of Manganese	[kg]	17	9	3	2	4	0	0
Weight of Lithium	[kg]	14	7	2	5	3	1,2	1,2

- This design option only has a low influence on the BOM (also there might be some exchanges to enable the reuse) and thus, the BOM and the connected data are the same as for the BAU of the Base Case.
- The major difference of this design options can be observed in the additional section marked in red.
- Lines are used for the calculation of the additional life time, the average energy delivered per cycle and finally the resulting additional FU provided by the battery in this timeframe.
- The total QFU is considered as the sum of both: the QFU from the first lifetime and from the re-use phase.

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3. Design option "Low carbon electricity mix"

- The usage of low-carbon electricity mix has no direct influence on the BOM or performance indicators
- ➢ Hence both are identical with those of the BAU for the Base Cases.

BaseCase		BC 1	BC 2	BC 3	BC 4	BC 5	BC6	BC7
Long Description		**Passenger Car - BEV with higher battery capacity**	**Passenger Car - BEV with lower battery capacity**	**Passenger Car PHEV**	**Truck BEV**	**Truck PHEV**	**Residential ESS**	**Grid stabilisation ESS**
Main application		eMobility					stationary	
Parameter	unit	BC 1	BC 2	BC 3	BC 4	BC 5	BC6	BC7
Typical capacity of the application	[kWh]	80	40	12	360	160	10	30.000
Economic life time of application (Tapp)	[y]	13	14	13	14	12	20	20
Percent of braking energy recovery in AS	[-]	20%	20%	20%	12%	6%	n.a.	n.a.
Application service energy (AS)	[kWh/Tapp]	43.680	29.568	19.656	940.800	890.400	40.000	120.000.000
Charger Efficiency (ηcharger)	[-]	85%	85%	85%	92%	92%	98%	98%
Consumption	[kWh/km]	0,2	0,16	0,18	1,2	1,4	n.a.	n.a.
Annual kilometers	[km/a]	14000	11000	7000	50000	50000	n.a.	n.a.
C-rate for charging	[-]	0,5	0,5	0,5	1,0	1,0	0,5	1,0
C-rate for normal discharge	[-]	1,0	1,0	1,0	1,0	1,0	1,0	1,0
C-rate for braking	[-]	3,0	3,0	3,0	3,0	3,0	3,0	3,0
Nominal battery system capacity according to ISO ..	[kWh]	80	40	12	30	20	10	10
Number of battery systems per application	[-]	1	1	1	12	8	1	3.000
Maximum calendar life-time of the installed battery (no cycling ageing)	[year]	20	20	20	20	20	25	25
Maximum SoC - maximum DoD (Stroke)	[-]	80%	80%	75%	80%	75%	80%	80%
Average stroke (SoC - DoD)	[-]	24%	31%	73%	50%	69%	60%	75%
Energy delivered in first cycle (Edc).	[kWh/cycle]	64	32	9	24	15	8	8
Number of cycles per year (#)	cycles	120	120	120	300	600	250	250
Maximum number of cycles for battery system until EoL (no calendar ageing)	[-]	1.500	1.500	2.000	2.000	3.000	8.000	10.000
SoH @ EoL of battery system relative to declared capacity (SoHcap)	[-]	80%	80%	60%	80%	60%	70%	70%
Average energy delivered per average cycle until EoL	[kWh/cycle]	19,44	12,22	8,75	178,57	110,06	6,00	22.500,00
number of batteries in the application	[year]	1,00	1,00	1,00	12,00	8,00	1,00	3.000,00
Actual quantity of functional units (QFU) over battery system lifetime (per battery) *(1 FU = 1 kWh over battery lifetime).*	[-]	40.320	23.642	13.440	482.297	373.177	25.532	95.744.681
Service life of first battery (years)	[year]	14,40	13,43	10,67	8,04	5,33	17,02	17,02
Battery system cost/declared initial capacity	[EURO/ kWh]	206	206	254	220	212	683	683
CAPEX for decomissioning	[EURO/ battery]	1.200	600	180	450	300	150	150
OPEX replace battery	[EURO/ battery]	700	700	700	400	400	100	100
ηcoul x ηv =average energy efficiency of battery system over life time	[-]	96%	96%	96%	96%	96%	96%	96%
Auxiliary heating energy for a battery system relative to functional unit	kW	5,0	5,0		5,0			
Self discharge per month(@STC)	[-]	2%	2%	2%	2%	2%	2%	2%
Total weight of a battery system	[kg]	609	304	126	256	210	128	128
Total weight of cells	[kg]	456	228	88	192	147	83	83
Specific energy density cell level	[Wh/kg]	175	175	136	156	136	120	120
Weight of Cobalt	[kg]	10	5	1	3	2	0	0
Weight of Graphite	[kg]	87	44	16	36	26	14	14
Weight of Nickel	[kg]	36	18	3	10	6	1	1
Weight of Manganese	[kg]	17	9	3	2	4	0	0
Weight of Lithium	[kg]	14	7	2	5	3	1,2	1,2

4) SUBTASK 6.4: ANALYSIS OF BAT AND LLCC

Possible positive or negative ('rebound') side effects of the individual design measures

Increased energy density

- A general potential rebound effect might result from the **substitution of materials with a low environmental impact by materials with a higher impact**, which could counter the positive effect from the reduction of material content.
- Due to the space becoming available in the battery, some **additional cells might be installed** to increase the battery capacity further. If the user profile stays the same this would lead again to an increased environmental impact.

Prolonged lifetime

- Batteries containing a high amount of **materials with a relative high environmental impact** (such as cobalt) could have a potentially higher positive influence **if they are directly recycled instead of reused**.
- **Batteries might be removed** before they are reaching a SOH of 70-80%, to guarantee that they are still usable for 2nd life applications.
- Or it is also thinkable that a battery is used for a 2nd life application, although it is **not anymore in the condition to provide the necessary service**.

Low-carbon energy mix

- The use of low-carbon energy mix might have a direct effect on the **production costs** of a battery system (depending on the specific electrify costs in the region).

5) TASK 6: FINAL REMARKS ON DESIGN OPTIONS

Final remarks

Please note:

- This is a first step analysis, with the **aim to generally assess if there is a positive impact due to a single design option.** In a following step those options can also be combined to determine best technical combinations
- Thus, **next steps** after the stakeholder meeting will be to **assess possible bundles of design options**.

Final remark:

- In general, the whole technology develops **very dynamically** and data availability is also very limited, thus it is **very difficult to give an outlook regarding performance and costs** even for the next 3-5 years.

THANK YOU FOR YOUR ATTENTION

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