FOR A COMPETITIVE, CIRCULAR AND SUSTAINABLE EUROPEAN BATTERY MANUFACTURING INDUSTRY.

D1.1 – Catalogue of data of the feedstock to be treated

Work Package 1 - Battery supply & deactivation

Task 1.1 - Specification of the feedstocks & inputs received from Gigafactory (scraps) and EoL modules and cells

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CONTENT

1 EXECUTIVE SUMMARY

D1.1 grant agreement description: The deliverable will catalogue the main Li-ion battery types and cells/modules or production scrap and will provide the main data like the type of cells, the range of state of health and charge, the electrical architecture, the chemistry, the dimension of module and arrangement of the cells and the weight.

This catalogue of feedstock provides a comprehensive list of the materials that can be used by all RESPECT project participants as input for the recycling process. It can serve as a reference to easily identify the different type of waste that can be recovered and optimize recycling methods.

This catalogue is structured in three parts:

1) *Specification of materials for lithium-ion battery recyclers*: Key specifications include physical dimensions, weight, chemistry, electrical performance, the range of state of health and charge, quality, suppliers etc. These specifications provide a standardized set of guidelines for the utilized recycling methods. It enables the comparison of different products and allows for informed decisions about which modules are best suited for the recycling process and which modules will require some methodological adaptations. The objective is to be able to efficiently treat the widest of variety of modules with the same approach. In addition, a similar approach for the most efficient treatment of scraps are also considered. It should be noted that the exact chemical composition of such storage components are difficult to identify due to industrial confidentiality. Moreover, as improvements are regularly made to batteries to increase their performance, therefore the chemical composition of batteries steadily changes over time. Nevertheless, currently the main materials involved in the manufacture of lithium-ion batteries are lithium, cobalt, nickel, manganese, and graphite - all of which have been identified as materials with availability and environmental risks.
2) *Future market intelligence*: An overview of the market to comprehend the scale of quantities that recyclers will have to process.
3) *Materials treated via RESPECT project*: This comprises a summary of the material needs. It includes information on the type of materials, their sources, when they should be delivered, to which partners, in which quantity and the treatment applied on it.

2 MATERIAL DEFINITION AND SPECIFICATION

2.1 Modules

2.1.1 Definition: Battery Cell, Module or Pack. What's the difference?

The component constituents that make up the battery power source in an EV can be split into three distinct parts: **Cell, Module** and **Pack**. Of these, the production of battery cells can be considered to a largely chemical-based process that provides the essential elements for the next stages i.e., the mechanical assembly of the battery modules and packs, which make up the superstructure of an EV's "electric engine". In simplistic terms, cell batteries act as a repository of reversible chemical reactions that can store electrical energy and which can be charged or discharged depending on the requirements. Generally, battery cells are available in a host of different configurations depending on the chemistry and intended application, although those used in the EV sector typically comprise of three main types: *cylindrical*, *pouch* and *prismatic*. To harness the power of cells collectively and facilitate subsequent vehicle assembly, battery cells are connected – either in parallel or series - to form modules with predetermined voltage and energy capacity requirements. These modules are finally enclosed together along with some form of temperature control, sensors, and other battery management system (BMS) electronics in a suitable configuration to form the power source for the desired EV application like car, van, or bus [1]

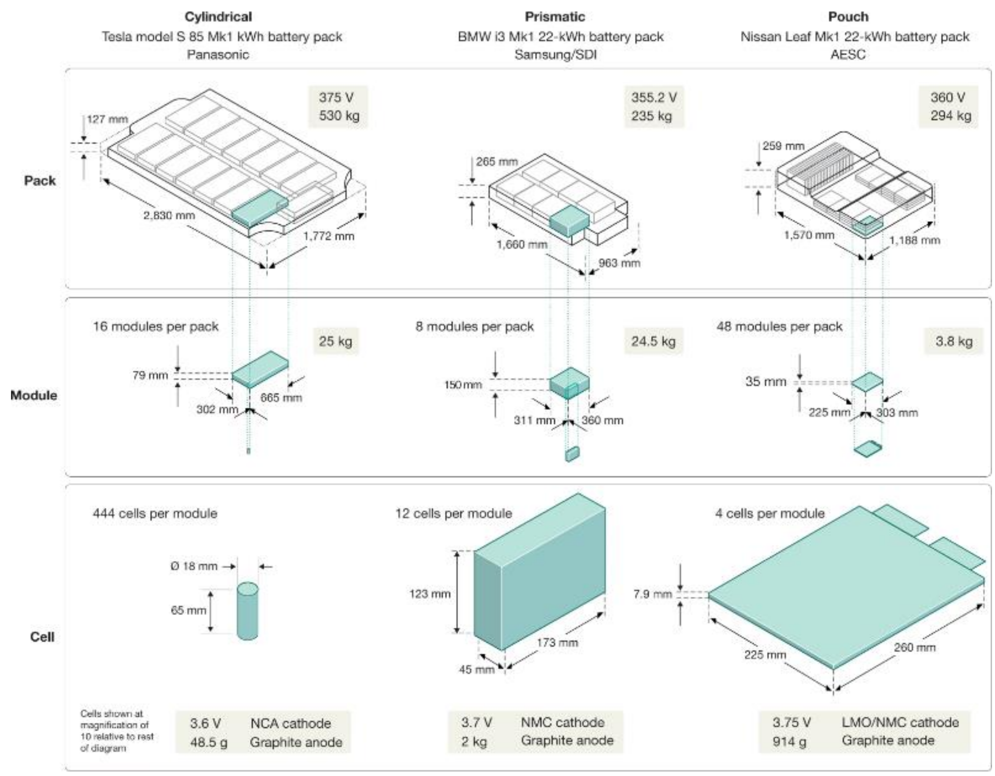


Figure 1 : Examples of three different battery packs and modules (cylindrical, prismatic and pouch cells) in use in current electric cars [2]

The three designs – outlined in Figure 1 - examined are from model year 2014; this is based on the availability of information from vehicle dismantling, and also as older model vehicles are the most likely to be closer to end-of-life (EoL) than new cars just entering the market.

2.1.2 Battery feedstock specifications

We gathered data on 30 different modules [3] put on the market in the last few years and that could be available for recycling in the period 2025-2030. We have carried out a detailed analysis for each modules' key characteristics based on the mean, standard deviation, maximum and minimum of different categories. As the batteries are not standardized, the variability of module specification could be very large, this catalogue should be considered as an initial draft based on existing technology. **N.B.** In this case, Tesla battery modules have been excluded from this assessment as the number of cylindrical cells are very high (up to 500 cells per module). [4] [5] [6] [7] [8] [9] [10] [11]

	Nominal Energy (Wh)	Capacity (Ah)	Tension (V)	Weight (Kg)	Width(cm)	Height(cm)	Length(cm)	Number of cells
Mean	5152	161.5	31.2	30.6	22.6	13.4	51.6	16.9
Standard variation	3902	72.3	18.0	24.1	10.1	5.3	20.4	10.9
Max	12597	326.0	77.3	76.6	44.5	22.4	91.6	56.0
Min	861	62.0	7.6	3.8	8.2	3.0	30.0	2.0

Table 1 : Overview of the key characteristic from a sample of modules currently available on the market

2.2 Scraps definition

During the battery manufacturing process, several types of scraps of production are generated corresponding to the different stages (Figure 2) and are detailed in the table below (Table 2).

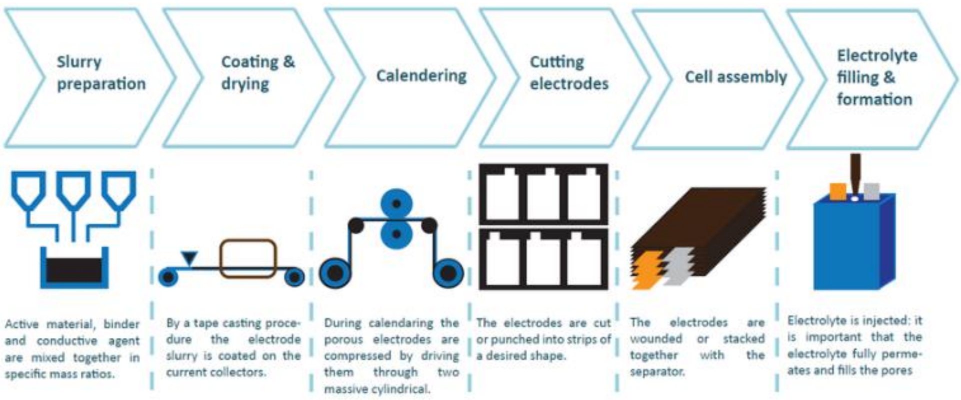


Figure 2 : Manufacturing steps of Li-ion batteries [12]

Main type of scrap	Description	Cell manufacturing process
Cathode ink/powder	NMC suspension or powder for cath-ode production	Electrode manufacturing
Aluminium foil	Aluminum foil before NMC coating	Electrode manufacturing
Copper foil	Copper foil before coating	Electrode manufacturing
Cathode electrode	NMC coated aluminum foil	Electrode manufacturing
Anode ink/powder	Graphite suspension or powder for anode production	Electrode manufacturing
Anode elecxtrode	Graphite coated copper foil	Electrode manufacturing
Dry stack	Stacked electrodes with separators in between	Cell assembly
Dry cells	Battery cells with stacked electrodes, separators, and casing before elec-trolyte filling	Cell assembly
Wet cells	Complete battery cells including electrolytes before charging step	Cell assembly
Charged cells	Complete battery cells after charging (that have failed validation process)	Validation

Table 2 : Main type of scrap materials generated during the manufacturing process

3 MATERIAL AVAILABLE ON THE MARKET

3.1 EoL modules expected for recycling

3.1.1 Cell structure

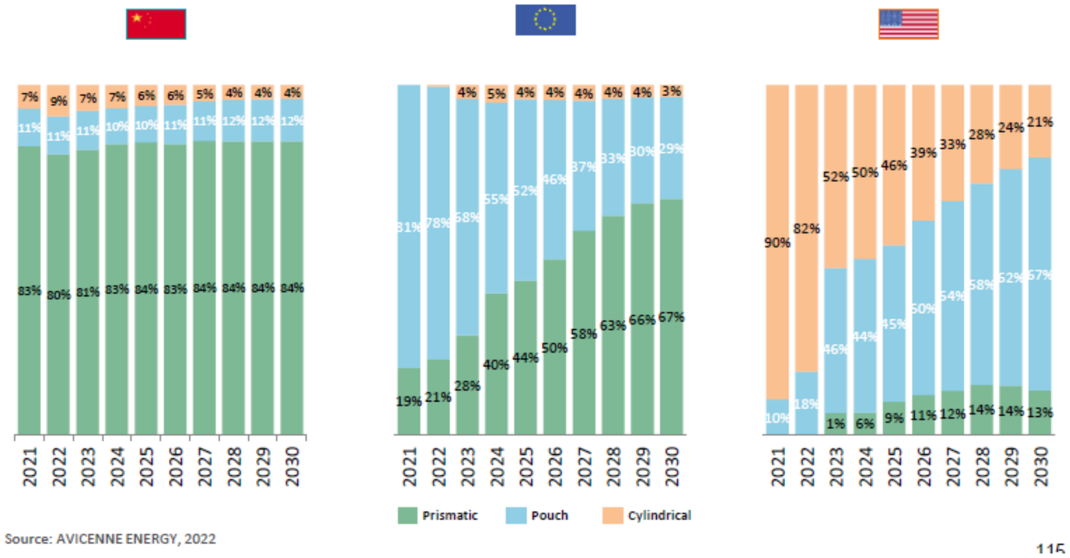


Figure 3 : Cell type by major regions % of GWh produced 2021-2030 [13]

According to a 2022 study led by Christophe PILLOT from Avicenne, prismatic cells provide over 80% of China's demand between 2021 and 2030. In contrast, by 2026 it is predicted that prismatic cells will overtake pouch cells in Europe, whereas pouch cells will predominate over cylindrical cells in the US market. Nevertheless, this is merely a forecast based on current trends, and therefore the data should be critically analysed as the EV market can change rapidly.

3.1.2 Chemistry

To predict the chemistry available for recycling in 2025-2030, a more in depth analysis of historic market trends during 2015-2020 is needed based on a battery life of about 10 years.

In **2015, LCO and NMC were the most common chemistries**, with a global production of approximately 148 000 tonnes. In **2021,** the **global production of active cathode materials** amounted to 1 263 000 tonnes, which **mostly NMC (46.2%)**, followed by **LFP** with a market share at **28.9%** and **NCA** at **11.9%** (Wood Mackenzie 2021). As can be seen from the data displayed in Table 3, nearly all chemistries – except for LCO - are predicted to show continued growth of at least 50% or more by 2030 compared with their respective 2021 production levels.

Cathode type	Unit	2015	2021	2025	2030	Production Increase (2021-2030)
NCM	kt	59	584	1 702	2 681	78%
LCO	kt	44	114	149	149	23%
LFP	kt	20	366	1 268	1 947	81%
NCA	kt	15	150	219	359	58%
LMO	kt	11	50	90	122	59%
TOTAL	kt	**148**	**1263**	**3429**	**5257**	**75%**

Table 3: Predicted changes in different cathode chemistries production from 2015 to 2030 [14]

A recent IDTechEx study [15] provides an alternative perspective. Currently and up until 2025, the chemistries available on a global scale for the Li-ion battery recycling market will be dominated by LCO and LFP batteries (Figure 4). This is a result of the fact that a majority of the Li-ion batteries reaching end-of-life in the next few years come from a combination of consumer electronics (which mainly use LCO batteries) and packs from electric buses in China (that are based on LFP batteries).

Nevertheless, beyond 2025 it is predicted that there will be a notable increase in the amounts of NMC batteries becoming available for recycling as a direct result of the growth in EV sales from approximately 2010 onwards. However, the IDtechex study predicts only a small share for LFP in the batteries available for recycling from 2025 onwards – with the exception of in China - which decreases thereafter. This is in contrast to the **IEA's projections** [16]**, which foresee a high production of LFP**, and therefore a lot of end-of-life batteries using this technology. It may be speculated that LFP will play a role in recycling throughout the 2030´s and that due to its poor recyclability in the state-of-the-art processes, it is of great importance to develop routes for non-linear economy for this battery fraction. NiMH batteries are considered as past technology in the electric vehicles (HEVs) and therefore not in the focus of future battery recycling operations.

3.1.3 Quantity

As the anticipated mass adoption of electric vehicles continues with almost exponential growth, **the amount of higher energy density NMC batteries that require recycling is forecast to reach almost 7 million tonnes per year by 2040** (Figure 4).

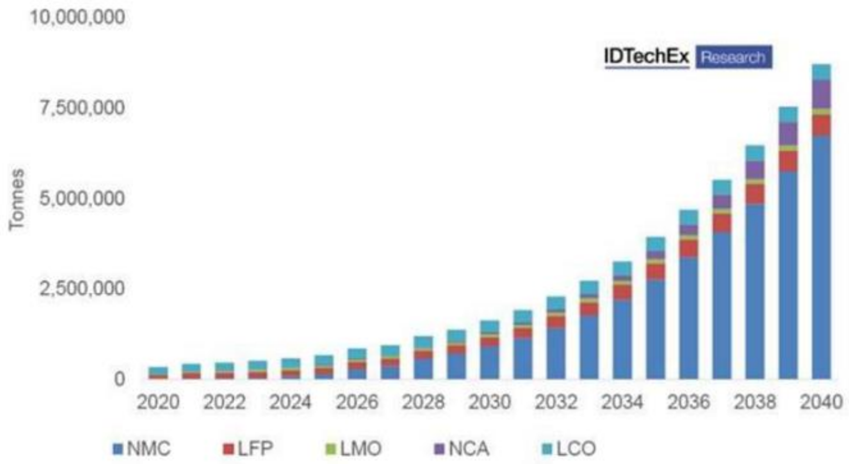


Figure 4 : Global forecast of available batteries - by chemistry - in tonnes up to 2040

As can be seen from Figure 5, from **a European perspective, the trends very much follow the Global predictions with a marked change from LCO to NMC chemistry from 2025 onwards and signifcant increase in the overall amounts available of all chemistries** - from ~**50,000 tonnes in 2020, 250 000 tonnes in 2030** to ~1.5 million tonnes by 2040. Nevertheless, such predictions do not necessarily take into account changes to the potential supply for recycling due to increased battery use in second-life applications or shifts in chemistries dictated by material availability as a result of future market and geo-political reasons.

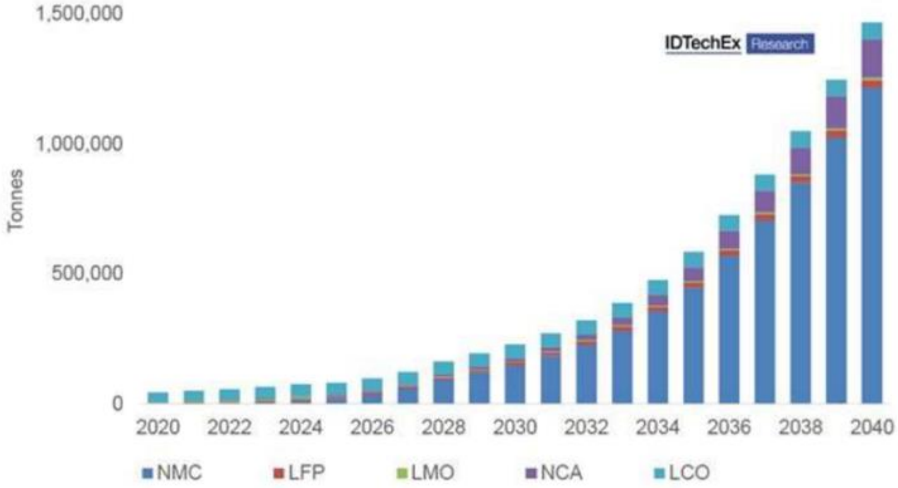


Figure 5 : Forecasted level of Li batteries for recycling in Europe 2040

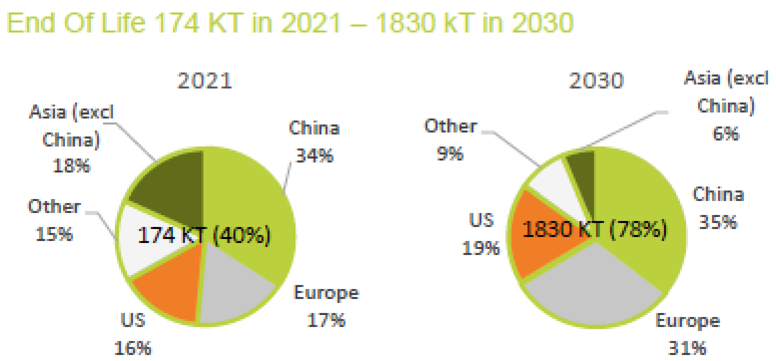


Figure 6 : Forecasted level of End of Life for recycling globally by 2030 [13]

The study carried out by Avicenne differs from IDTechex. Europe would have to treat about **30,000 tons of end-of-life batteries in its recycling sector in 2021**. In **2030, it would have to treat 567,000 tons of end-of-life batteries.**

3.2 Manufacturing scrap expected for recycling in 2030

3.2.1 Type

Type of Scrap	%
Cathode electrode	10 - 20
Anode electrode	10 - 20
Electrode stack	10 - 20
Dry cell	20 - 30
Wet cell with electrolyte	20 - 25
Activated wet cell	10 - 20

Table 4 : Proportion of forecasted scrap in 2030

The type of scrap that will be mostly available on the market relates to almost finished cells without electrolyte and before load cycles (Table 4). This has the benefit of assisting recycling logistics in term of handling and transport as these types of materials will be consider as a non-hazardous waste. As outlined previously, the presence of electrolyte is a critical barrier to the facile recycling of these scraps due to the related chemical hazard and transport regulations.

3.2.2 Chemistry

Current and future market situation helps us to understand which technologies we should target to the recycling of battery scrap (*cf*. Table 4). Due to its high energy density, NMC, especially the latest generations, will form the majority of the different cell chemistries present in electric vehicles, closely followed by the LFP. Direct recycling could be preferred to conventional recycling route if it can be developed and if it is both economically and environmentally competitive. Furthermore, it is worth noting that hybrid technologies such as NCMA or LNMO are also in development for market application from around 2030 onward, whilst traditional chemistries like NCA will have reduced market share.

3.2.3 Quantity

Lithium-ion scraps are the discarded unusable material from manufacturing lithium-ion batteries. According to a recent study carried out by Avicenne Energy in 2022 [13], the overall level of scrap production on a European level in 2021 amounted to ~19 000 tons. However, with several new gigafactories planning to begin full scale manufacture and the increase in the need for batteries mainly related to electric mobility in Europe means there will be a significant increase in the amount of scrap by 2030. Avicenne predicts that by 2030, out of 510 000 tons of scraps destined for recycling globally, 132 600 tons will be produced and available in Europe.

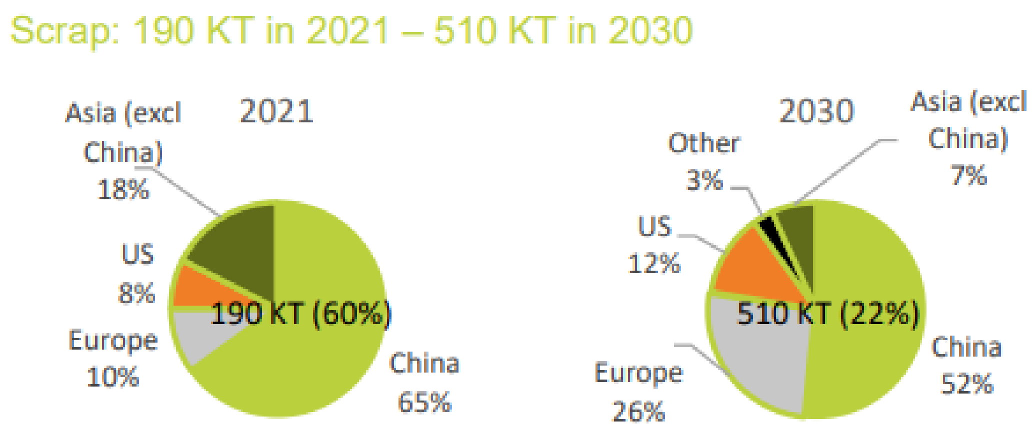


Figure 7: Forecasted level of scraps for recycling globally by 2030 [13]

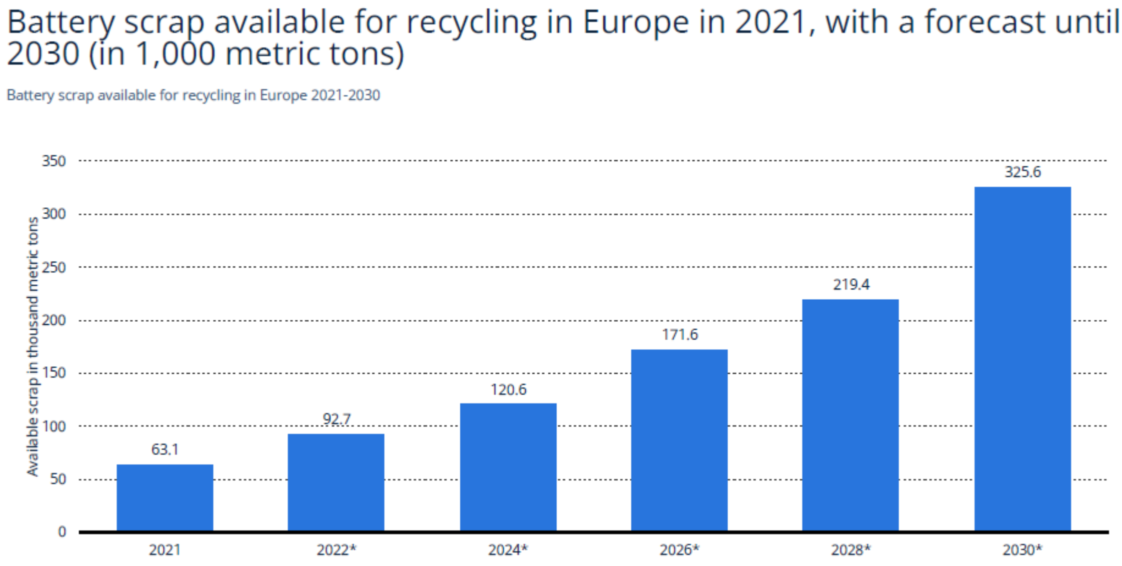


Figure 8 : Battery scrap available for recycling in Europe in 2021, with a forecast until 2030 [17]

In contrast, a recent Bloomberg report estimates the level of scrap will be significantly higher. Based on their analysis, in 2021, the number of scrap destined for recycling was 63.1KT/year. In 2030, the quantities predicted by the study would amount to nearly 325.6KT/year. It should be noted that it is still difficult to determine the level of scrap from gigafactories to be recycled by 2030, although it should represent between 20 and 30% of the total quantity of lithium-ion batteries to be recycled in the European region.

A study from Roland Berger 2022 [18] estimated that the scrap amount would be around 249KT/year in 2030, which is more like the Bloomberg prediction than that by Avicenne. Nonetheless, it can be expected that with the future introduction of new equipment or cell chemistries there may be substantial scrappage rates during the testing and ramp-up phases. According to Avicenne Energy, in total, the best scrappage rate in class could reach as low as 5%, whereas during the startup phases, the same rate can exceed 20 to 30% over a very long period.

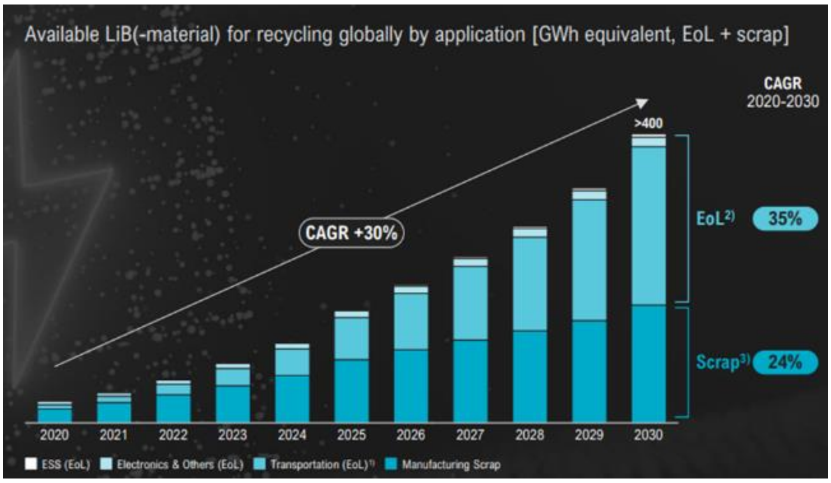


Figure 9 : Predicted total available LiB material for recycling globally by 2030 [18]

4 MATERIAL SHARING FOR RESPECT PROJECT

4.1 Starting material distribution

Two main materials will be provided during the realization of the RESPECT project's task. Scrap provided by Morrow from the start of its Gigafactory and End of Life (EoL) modules provided by Orano through its link to a battery supplier. As Morrow's Norwegian gigafactory will not be in production during the initial period of the RESPECT project, Morrow has decided to send the first batch of scrap from Korea - where the equipment and battery line are developed - as representative materials of genuine manufacturing scrap.

Concurrently, LFP batteries from stationary applications will be provided by Orano with 2 modules of around 30 kg being available in April. Nevertheless, it has been proposed by Orano that work carried out during 2023 will concentrate on LFP scrap rather than end-of-life modules - a point that still needs to be discussed and agreed with RESPECT partners.

Initial material	from	Quantity (kg)	expected delivery
Morrow - prismatic cells - Batch 1	Morrow	5-10 cells for CEA	June 2023
Morrow - NMC scraps - Batch 1	Morrow	7kg of cathode scraps and 10kg of anode scraps for CEA in 2023. 25kg of cathode scraps and 40kg of anode scraps for Orano to produce enough material for all the partners at project start in 2023. 150kg of cathode scraps to be treated at the beginning of 2024 and to be sent to Metso +150kg of anode scraps	March - April 2023
EoL Modules NMC - Batch 1	Orano/ Orano' supplier	10 modules including 1 for CEA to be deactivated. 500kg of modules in 2024	march - April 2023
EoL modules LFP - Batch 1	Orano's supplier	30kg (2 modules)	March - April 2023

Table 5 : Starting material sources and proposed quantities

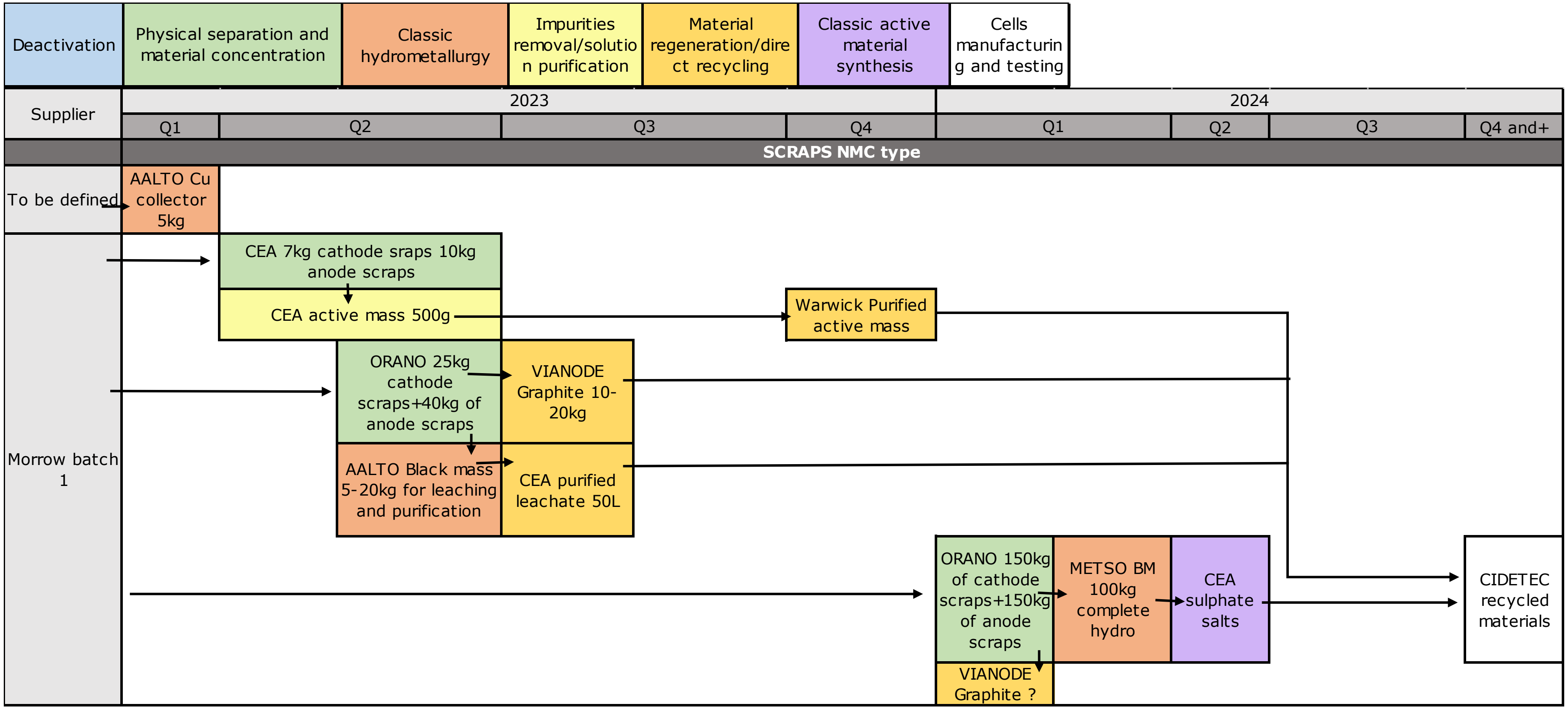
Project	Scraps							
Treated via RESPECT	Provider	Type of scraps	Cathodic active material in wt%	Anodic active material in wt%	Electrolyte in wt%	Other materials (support, binder…)	UN numbers	Chemical hazard
YES	Morrow	Cathode foils/coils	90	Not relevant	Not relevant	10	not applicable (non-dangerous)	H330 Fatal if inhaled H350 May cause cancer by inhalation H372 Causes damage to organs (Lung) through prolonged or repeated exposure (inhalation). H402 Harmful to aquatic life H412 Harmful to aquatic life with long-lasting effect
YES	Morrow	Anode coils / foils	Not relevant	70	Not relevant	30	not applicable (non-dangerous)	H351 Contains a component suspected of causing cance
YES	Morrow	Dry cells	51	24	not relevant	25		
YES	Morrow	Wet cells	46	21	12	21	UN3480 (dangerous goods)	Class-primary 9, Hazchem Code: 4W
YES	Morrow	Charged cells	46	21	12	21		

Table 6 : Specification of scrap to be treated via the RESPECT project

4.2 Timeline of material distribution

For each material, a timeline for distribution has been created in order to understand the material flows, the treatment applied, and the partners involved

4.2.1 SCRAP: NMC type



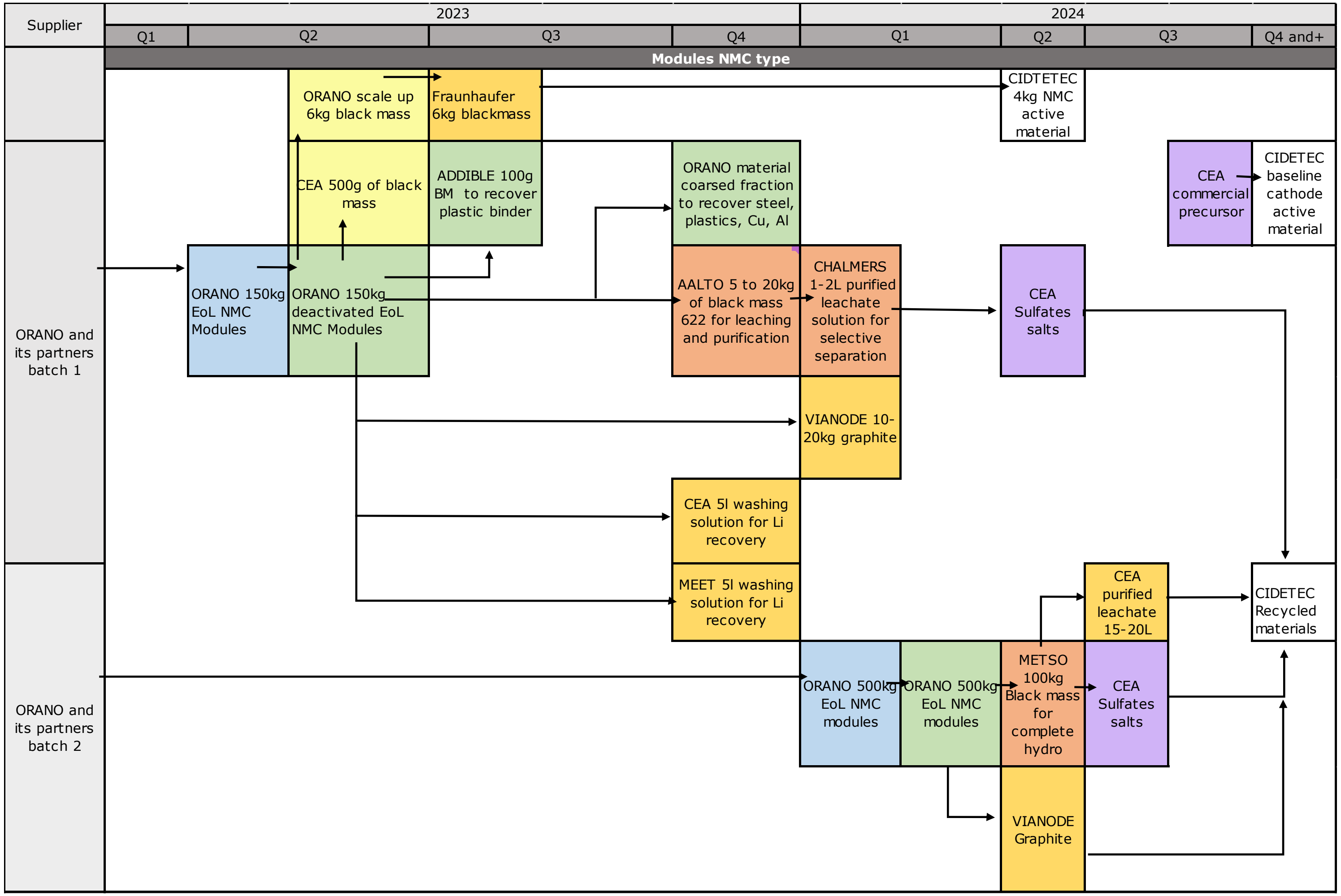
4.2.2 CELLS: NMC type

Deactivation	Physical separation and material concentration	Classic hydrometallurgy	Impurities removal/solution purification	Material regeneration/direct recycling	Classic active material synthesis	Cells manufacturing and testing

Supplier	2023				2024			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4 and+
Cells NMC type								
Morrow	→	CEA/Coup'indus 10 prismatic cells with different SoH						

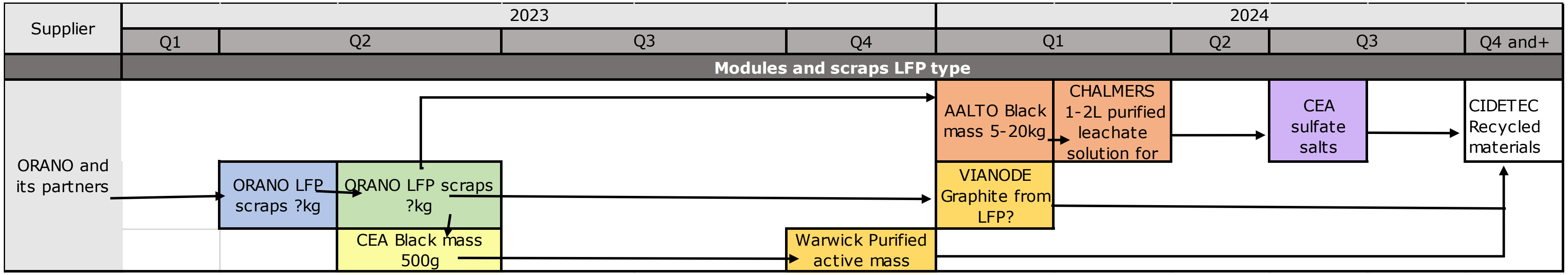
4.2.3 MODULES: NMC type

Deactivation	Physical separation and material concentration	Classic hydrometallurgy	Impurities removal/solution purification	Material regeneration/direct recycling	Classic active material synthesis	Cells manufacturing and testing

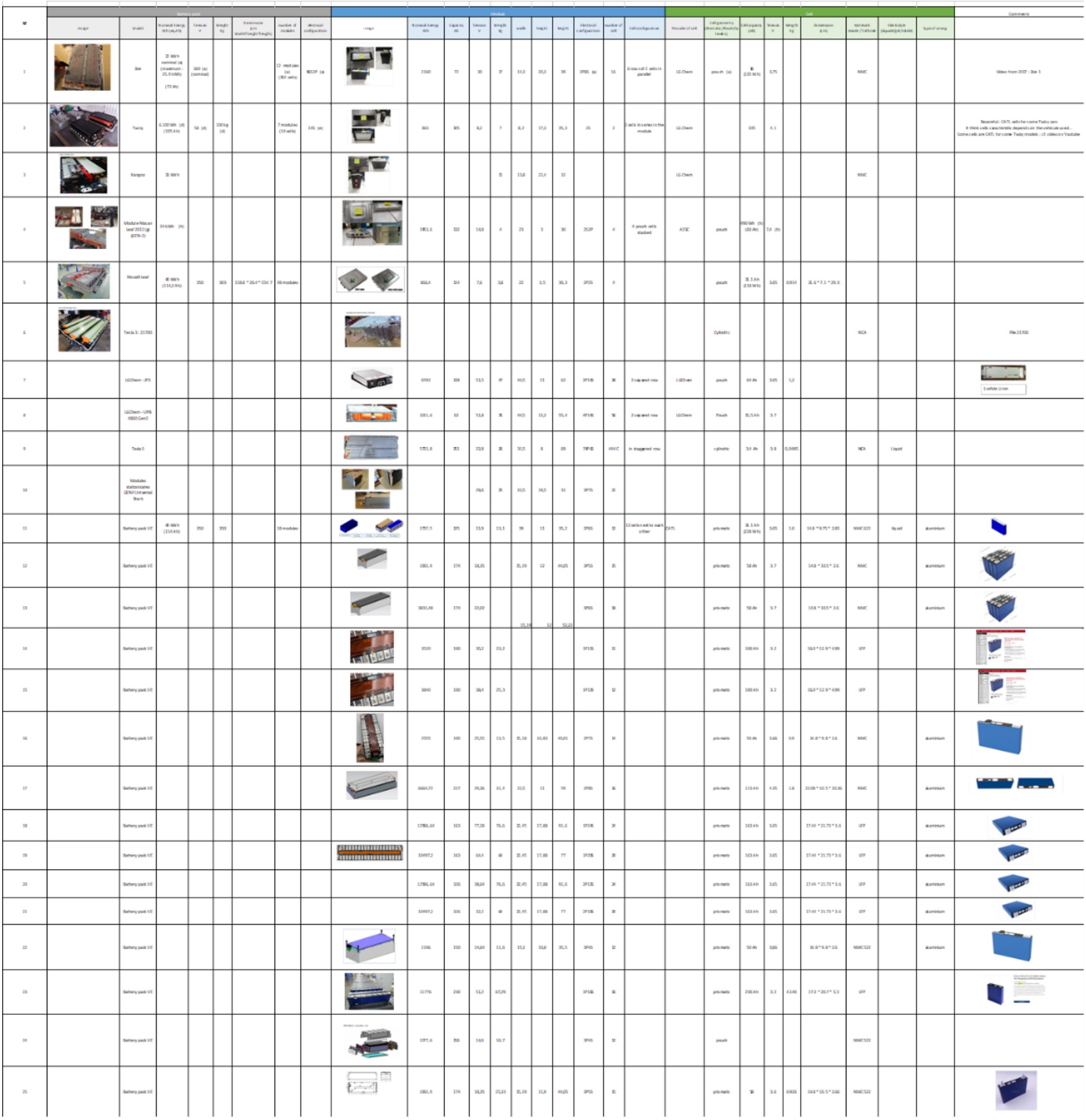


4.2.4 MODULES: LFP type

Deactivation	Physical separation and material concentration	Classic hydrometallurgy	Impurities removal/solution purification	Material regeneration/direct recycling	Classic active material synthesis	Cells manufacturing and testing



5 ANNEX



N°	Battery pack: image	model	Nominal energy kWh (Ah)	Tension V	Weight kg	Dimension pack	number of modules	electrical configuration	Module: image	Nominal energy Wh	Capacity Ah	Tension V	Weight kg	width	height	length	electrical configuration	number of cell	cell configuration	Cell: provider of cell	cell geometry	cell capacity (Ah)	Tension V	Weight kg	Dimension (cm)	Materials anode/cathode	Electrolyte	Type of casing	Comments
1		Zoe	22 kWh nominal (maximum : 25.9 kWh) (73 Ah)	360 (nominal)			12 modules (192 cells)	96S2P		1560	73	30	17	14,3	20,3	39	2P8S	16	8 rows of 2 cells in parallel	LG Chem	pouch	36 (135 Wh)	3,75			NMC			Video from 2017 - Zoé 1
2		Twizy	6 100 Wh (105 Ah)	58	100 kg		7 modules (14 cells)	14S		861	105	8,2	7	8,2	17,3	35,3	2S	2	2 cells in series in the module	LG Chem		105	4.1						Beware!: CATL cells for some Twizy cars. I think cells caracteristic depends on the vehicule used... Some cells are CATL for some Twizy models : cf videos on Youtube
3		Kangoo	33 kWh										15	13,8	22,4	32				LG Chem						NMC			
4		Module Nissan Leaf 2012 (gen-1)	24 kWh							1953,6	132	14,8	4	23	3	30	2S2P	4	4 pouch cells stacked	AESC	pouch	480 Wh (60 Ah)	7,4						
5		Nissan Leaf	40 kWh (114,2 Ah)	350	303	118.8 * 26.4 * 154.7	48 modules			866,4	114	7,6	3,8	22	3,5	30,3	2P2S	4			pouch	31.1 Ah (118 Wh)	3,65	0.914	21.6 * 7.1 * 29.0				
6		Tesla 3 : 21700																			Cylindric					NCA			Pile 21700
7		LGChem - JP3								6502	128	51,5	47	44,5	11	62	2P14S	28	2 separed row	LGChem	pouch	64 Ah	3,65	1,2					1 cellule Li-ion
8		LGChem - UPB 4860 Gen2								3251,6	62	51,8	35	44,5	12,2	55,4	4P14S	56	2 separed row	LGChem	Pouch	15,5 Ah	3.7						
9		Tesla S								5351,8	251	22,8	26	30,5	8	69	74P6S	444C	in staggered row		cylindric	3.4 Ah	3.8	0,0485		NCA	Liquid		
10		Modules stationnaires GENH Universal Stack										29,6	25	33,5	18,5	31	3P7S	21											
11		Battery pack VE	40 kWh (114 Ah)	350	350		16 modules			2797,5	125	21,9	13,1	39	11	35,2	2P6S	12	12 cells next to each other	CATL	prismatic	31.1 Ah (228 Wh)	3,65	1.0	14.8 * 9.75 * 2.65	NMC622	liquid	aluminium	
12		Battery pack VE								3180,9	174	18,35		15,19	12	44,05	3P5S	15			prismatic	58 Ah	3.7		14.8 * 10.5 * 2.6	NMC		aluminium	
13		Battery pack VE								3831,48	174	22,02		15,19	12	52,22	3P6S	18			prismatic	58 Ah	3.7		14.8 * 10.5 * 2.6	NMC		aluminium	
14		Battery pack VE								3520	100	35,2	23,2				1P11S	11			prismatic	100 Ah	3.2		16.0 * 12.9 * 4.99	LFP			
15		Battery pack VE								3840	100	38,4	25,3				1P12S	12			prismatic	100 Ah	3.2		16.0 * 12.9 * 4.99	LFP			
16		Battery pack VE								2555	100	25,55	13,5	15,18	10,83	40,01	2P7S	14			prismatic	50 Ah	3.65	0.9	14.8 * 9.8 * 2.6	NMC		aluminium	
17		Battery pack VE								6664,72	227	29,36	31,4	22,5	11	59	2P8S	16			prismatic	113 Ah	4.35	1.8	22.08 * 10.5 * 33.36	NMC		aluminium	
18		Battery pack VE								12586,64	163	77,28	76,6	22,45	17,88	91,6	1P24S	24			prismatic	163 Ah	3.05		17.44 * 21.73 * 3.6	LFP		aluminium	
19		Battery pack VE								10497,2	163	64,4	60	22,45	17,88	77	1P20S	20			prismatic	163 Ah	3.05		17.44 * 21.73 * 3.6	LFP		aluminium	
20		Battery pack VE								12586,64	326	38,64	76,6	22,45	17,88	91,6	2P12S	24			prismatic	163 Ah	3.05		17.44 * 21.73 * 3.6	LFP		aluminium	
21		Battery pack VE								10497,2	326	32,2	60	22,45	17,88	77	2P10S	20			prismatic	163 Ah	3.05		17.44 * 21.73 * 3.6	LFP		aluminium	
22		Battery pack VE								2196	150	14,64	11,6	15,1	10,8	35,5	3P4S	12			prismatic	50 Ah	3.66		14.8 * 9.8 * 2.6	NMC532		aluminium	
23		Battery pack VE								11776	230	51,2	67,29				1P16S	16			prismatic	230 Ah	3.2	4.140	17.3 * 20.7 * 5.3	LFP			
24		Battery pack VE								2277,6	156	14,6	10,7				3P4S	12			pouch					NMC532			
25		Battery pack VE								3180,9	174	18,35	15,33	15,19	11,9	44,05	3P5S	15			prismatic	58	3.6	0.926	14.8 * 10.5 * 2.66	NMC532			

Table 7 : Catalogue of modules considered [3] : 2023_02_22_Materials feedstock catalog_module.xlsx

	initial material	from	Quantity (kg)	expected delivery	output type	Quantity	to ?
WP1 BATTERY SUPPLY AND DEACTIVATION							
1.3 Sourcing materials for the other WPs							
1.3.1 Sourcing of cells	Morrow - prismatic cells - batch 1	Morrow	5-10 cells for CEA	June 2023	cells (prismatic, pouch, cylindrical)		
1.3.2 Sourcing of NMC scraps	Morrow - NMC scraps - Batch 1	Morrow	7kg of cathode scraps and 10kg of anode scraps for CEA in 2023. 25kg of cathode scraps and 40kg of anode scraps for Orano to produce enough material for all the partners at project start in 2023. 150kg of cathode scraps to be treated at the beginning of 2024 and to be sent to Metso +150kg of anode scraps	March - April 2023	anode and cathode scraps NMC	25	
1.3.3 Sourcing of EoL modules NMC	GV - EoL Modules NMC - Batch 1	Orano/ Orano'supplier (GV)	10 modules including 1 for CEA to be deactivated. 500kg of modules in 2024	march - April 2023	EoL modules NMC	200	
1.3.4 Sourcing of EoL modules LFP	SAFT - EoL modules LFP - Batch 1	Saft (TBC)	30kg (2 modules)	March - April 2023	EoL modules LFP	200	
1.3 Safe opening and deactivation							
1.3.5 First testing and optimization - with prismatic cells and modu	Morrow - prismatic cells - batch 1	Morrow	5 prismatic cells with different SoH (70 to 100%)	June 2023	deactivated modules and cells	5 deactivated cells	Coup'indus /CEA
1.3.5 First testing and optimization - with modules	GV - EoL Modules NMC - Batch 1	Orano	1 module	Q2 2023	deactivated modules	1 deactivated modules	Coup'indus /CEA
1.3.6 Deactivation of EoL Modules NMC	GV - EoL Modules NMC - Batch 1	Orano	200-500kg	Q2 2023	deactivated modules NMC	) kg of deactivated m	Orano, CEA
1.3.7 Deactivation of EoL Modules LFP	SAFT - EoL modules LFP - Batch 1	Orano	30kg	Q2 2023	deactivated modules LFP	around 2-3 modules	Orano
WP2 : PRETREATMENT FOR MATERIALS CONCENTRATION							
2.1 Module cutting							
2.1.2 Testing on commercial modules	GV - EoL Modules NMC - Batch 1	CEA	1 VWID3, 1 BMWI3, 1 Tesla, 2 Nissan Leaf	End of January 2023	extracted cathode and foils NMC		X
2.1.3 Validation on EoL modules NMC	GV - EoL Modules NMC - Batch 1	Orano	?	Q4 2023 / Q1 2024	extracted cathode and foils NMC		CEA
2.1.4 Cutting with Orano's conventional cutting machine	GV - EoL Modules NMC - Batch 1	Orano	10 modules including 1 for CEA to be deactivated. 500kg of modules in 2024	Q2 2023	extracted cathode and foils NMC		CEA
2.2 Selective separation from graphite and deactivated batteries - NMC							
2.2.1 Testing and optimization on NMC scraps	Morrow - NMC scraps - Batch 1	Morrow	15kg	Q2 2023	black mass, graphite - NMC & washing solution	15kg	
2.2.2 Testing on extracted electrodes NMC from task 2.1	GV - EoL Modules NMC - Batch 1	Orano	eatment of the 150kg of sourced modules for 202	Q3-Q4 2023	black mass, graphite - NMC & washing solution		Aalto
2.2.3 Testing on NMC scraps with the pilot of Orano	Morrow - NMC scraps - Batch 1	Morrow	25kg of cathode scraps and 60kg of anode scraps	?	black mass, graphite - NMC & washing solution		Aalto, T3.1
2.2.4 Testing on extracted electrodes LFP from task 2.1	SAFT - EoL modules LFP - Batch 1	Orano	30kg modules	Q3 2023	black mass, graphite - LFP & washing solution	5kg	CEA, Orano
2.3 Lithium recovery from electrolyte							
2.3.1 Testing on the washing solution of 2.2 - supercritical CO2 and	GV - EoL Modules NMC - Batch 1	Orano	5L	Q4 2023	recovered Li	eeds to be estimate	X
2.3.2 Testing on the washing solution of 2.2 - electrochemical lithiu	GV - EoL Modules NMC - Batch 1	Orano	5L	Q4 2023	recovered Li	eeds to be estimate	X
2.4 Physical separation process and valorisation : steel; plastics, Al, Cu							
2.4.1 Testing on coarse and intermediary fraction of 2.2	GV - EoL Modules NMC - Batch 1	Orano	~ 1000kg of coarsed fraction		recovered materials after mechanical sorting (Al, Cu, Fe, BM)		X
2.4.2 Recovery of some plastics after the physical separation	GV - EoL Modules NMC - Batch 1	Orano	Small samples of black mass for lab-scale testing	Q2/Q3 2023	cled plastics after chemical treatment		X
2.4.3 Recovered Cu (Orano) and Production Scrap (Morrow)	Morrow - NMC scraps - Batch 1	Orano	rom recovered (Orano) and Production Scrap (Mc	Q1 2023 if possible	action used ac chemical reductants for WP3		Aalto, T3.1
WP3 INOVATIVE AND LOW ENVIRONMENTAL IMPACT HYDROMETALLURGY							
3.1 Innovative and flexible leaching of battery waste							
3.1.1 Testing on commercial black mass	?	?	Minimum 5 Kg for lab-scale testing (Max ~20kg)	end of 2023	leachate solution NMC		
3.1.2 Testing on NMC black mass from 2.2 NMC 622 and 811	GV - EoL Modules NMC - Batch 1 and Morrow NMC scraps	Orano	Minimum 5 Kg for lab-scale testing (Max ~20kg)	end of 2023	leachate solution NMC		Metso
3.1.3 Testing on LFP black mass from 2.2 (potentially combined wit	SAFT - EoL modules LFP - Batch 1	CEA	Minimum 5 Kg for lab-scale testing (Max ~20kg)	end of 2023	Leachate solution LFP (may be combined with NMC)		Metso
3.1.4 Pre-production scrap copper and/or copper from separation b	Morrow - NMC scraps - Batch 1	Orano	1 to 10kg	end of Q1 2023	Leachate solution		Metso
3.2 Selective solution purification							
3.2.1 Testing on leachate solution from 3.1 - NMC (obs. potentially	GV - EoL Modules NMC - Batch 1 and Morrow NMC scraps	Aalto	Detailed analysis (with potentially 1-2L sample)		purified leachate solution NMC (with potentially LFP)		Chalmers
3.2.2 Testing on leachate solution from 3.1 - LFP	SAFT - EoL modules LFP - Batch 1	Aalto	Detailed analysis (with potentially 1-2L sample)		purified leachate solution LFP		Chalmers
3.3 Selective separation					separated transition metals		
3.3.1 Testing on purified leachate from 3.2 - NMC	GV - EoL Modules NMC - Batch 1 and Morrow NMC scraps	Metso	Detailed analysis (metallic and non-metallic elements) 15-20L		Co, Ni, Mn sulfates		CEA
3.4 Engineering hydrometallurgical process							
3.4.1 Validation of the pilot with a batch of black mass from 2.2	GV - EoL Modules NMC - Batch 1 and Morrow NMC scraps	Orano	100		Co, Ni, Mn sulfates	100kg	
3.5 pre-purification to support direct cathode regeneration							
3.5.1 Proof of concept and testing and on BM coming from NMC scr	Morrow - NMC scraps - Batch 1	Orano or CEA	500g	Q2 2023	purified black mass	400g	X
3.5.2 Proof of concept and testing and on BM coming from EoL NM	GV - EoL Modules NMC - Batch 1	Orano or CEA	500g	Q3 2023			X
3.5.3 Proof of concept and testing and on BM coming from EoL LFP	SAFT - EoL modules LFP - Batch 1	Orano	1.5x needs for regeneration (to be defined)	Q2 2023	purified black mass		JM
3.5.4 Scale-up and testing on the black mass produced from NMC s	Morrow - NMC scraps - Batch 1	Orano	1.5x needs for regeneration (to be defined)				JM
3.5.5 Scale-up and testing on the black mass produced from extrac	GV - EoL Modules NMC - Batch 1	Orano	6	Q2 2023	purified black mass	6kg	Fraunhofer
WP4 DIRECT RECYCLING AND ACTIVE MATERIAL SYNTHESIS							
4.1 Direct recycling of materials from scraps							
4.1.1 Production of high-quality graphite based on recovered grapl	Morrow - NMC scraps - Batch 1	Orano	at least 4kg, up to 20-30kg	Q1 2024	synthetized graphite	1 to 10kg	CIDETEC
4.1.2 Testing on the purified black mass from 3.5 - cathode scraps N	Morrow - NMC scraps - Batch 1	CEA	100g	Q3 2023	NMC active material	10g to 1kg	CIDETEC
4.2.direct recycling of cathode materials from end of life batteries							
4.2.1 Testing on the purified black mass from 3.5 - EoL modules NM	GV - EoL Modules NMC - Batch 1	Orano	4kg	Q3 2023	NMC active material		CIDETEC
4.2.2. Testing on the purified black mass from 3.5 - LFP	SAFT - EoL modules LFP - Batch 1	CEA	100g	Q3 2023	LFP active material	10g to 1kg	CIDETEC
4.3 active materials synthesis from HM outputs							
4.3.1 Production of high-quality graphite based on recovered grapl	GV - EoL Modules NMC - Batch 1	Aalto	at least 4kg, up to 20-30kg	Q4 2023 / Q1 2024	synthetized graphite	1 to 10kg	CIDETEC
4.3.2 Synthesis of NMC 811 based on Co, Ni,Mn salts produced in W	GV - EoL Modules NMC - Batch 1 and Morrow NMC scraps	Chalmers	Lab scale : 0.870 Kg NiSO4.6H2O 0.090 Kg MnSO4.H2O 0.140 Kg CoSO4.7H2O. Pilot scale 34 Kg NiSO4.6H2O 2,8 Kg MnSO4.H2O 4,6 Kg CoSO4.7H2O.	Q2/Q3 2023 : for lab scale Q2/Q3 2024 : Pilot scale	NMC active material	?	CIDETEC
4.3.3 Synthesis of NMC material based on the purified leachate sol	GV - EoL Modules NMC - Batch 1 and Morrow NMC scraps	Metso	300L	Q2/Q3 2023 : 50L for lab development (several samples of at least 10L are possible) Q2/Q3 2024 : 250L for pilot development and production	NMC active material		CIDETEC
4.4 Recycling processes validation						25 pouch cells	
4.4.1 synthetized graphite from scraps T4.1	Morrow - NMC scraps - Batch 1	Vianode	10,00	4.3.2	pouch cells		
4.4.2 NMC active material from scraps T4.1	Morrow - NMC scraps - Batch 1	JM	> 1	4.3.2	pouch cells		
4.4.3 NMC active material from EOL batteries T4.2	GV - EoL Modules NMC - Batch 1	Fraunhofer	> 1	4.3.2	pouch cells		
4.4.4 LFP active material from EOL batteries T4.2	SAFT - EoL modules LFP - Batch 1	JM	> 1	4.3.2	pouch cells		
4.4.5 synthetized graphite from HM T4.3	GV - EoL Modules NMC - Batch 1	Aalto	10,00	4.3.2	pouch cells		
4.4.6 NMC active material from HM T4.3	GV - EoL Modules NMC - Batch 1 and Morrow NMC scraps	Chalmers	> 1	4.3.2	pouch cells		
4.4.7 NMC active material from HM T4.3	GV - EoL Modules NMC - Batch 1 and Morrow NMC scraps	Metso	> 1	4.3.2	pouch cells		
4.4.8References materials (scraps?)		Orano or CEA	> 1	4.3.2	pouch cells		

Table 8 : Source and destination of different materials required throughout the lifetime of the RESPECT project

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7 FIGURES

8 TABLES