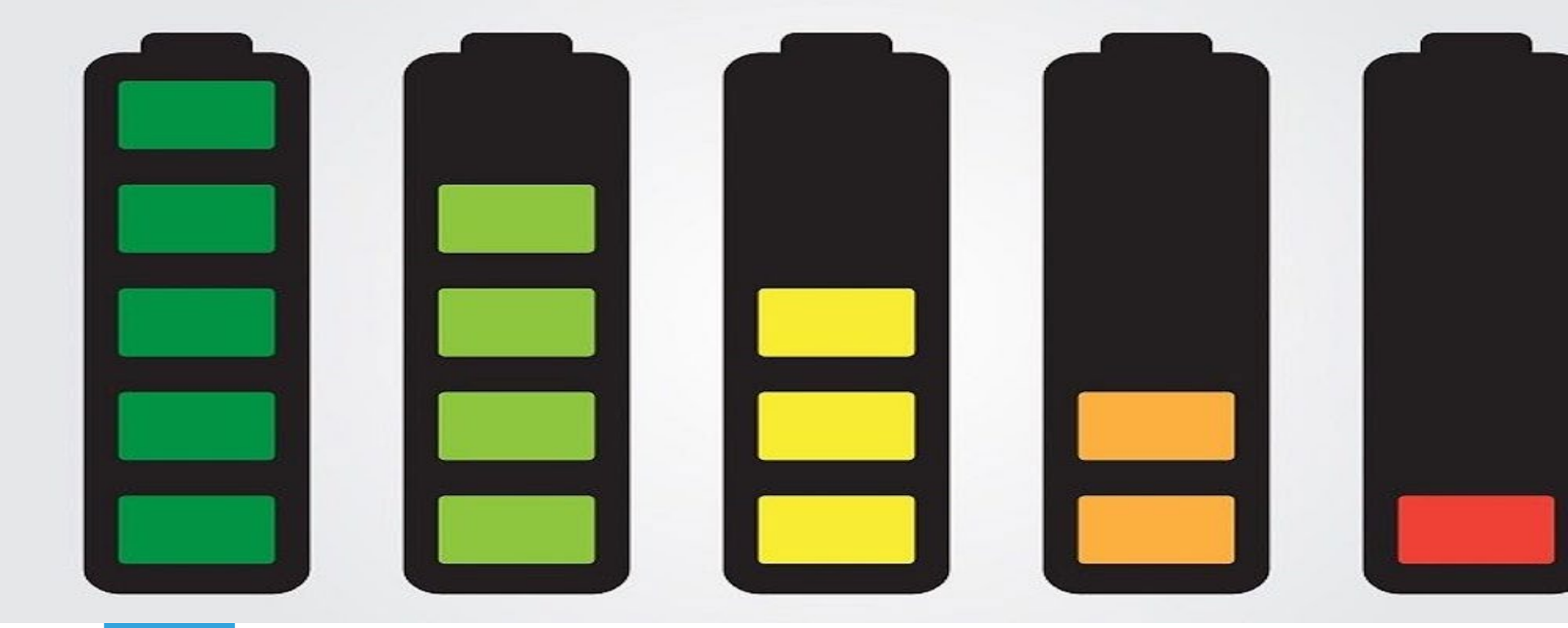


ECODESIGN BATTERIES – TASK 1

Paul Van Tichelen, Grietus Mulder, Tatiana Pasquel Garcia, Clemens Rohde, Antoine Durand, Tim Hettesheimer, Jan Viegand

viegand maagøe
energy people

Fraunhofer ISI

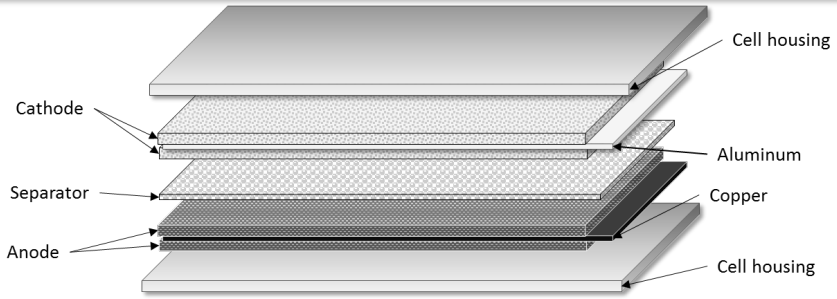
vito

SCOPE (DEFINITIONS, STANDARDS AND LEGISLATION) – FOR ECODESIGN AND ENERGY LABELLING

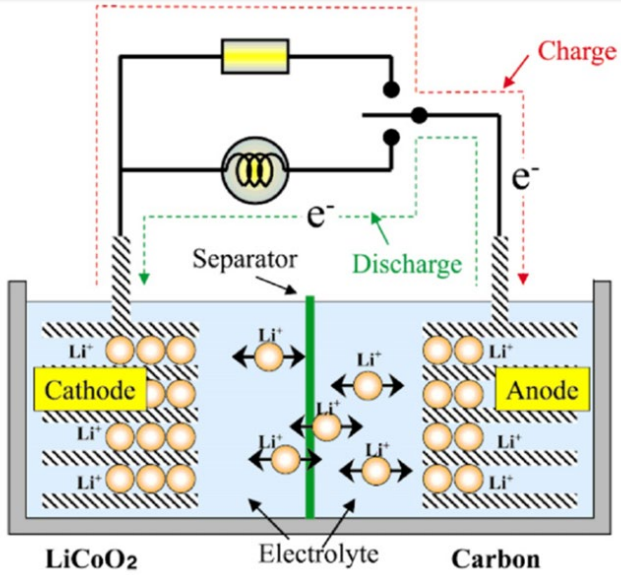
Objectives:

- Provide an **introduction** into **battery technologies**
- Provide **definitions & product categories** to defined the scope and boundaries of the system
- Define the **functional unit of the product** in order to have a consistent Life Cycle Analysis and Cost Analysis later on Tasks 2-6
- Review of existing **standards and legislation,** what are appropriate test standards and gaps

DEFINITIONS – What is a battery?



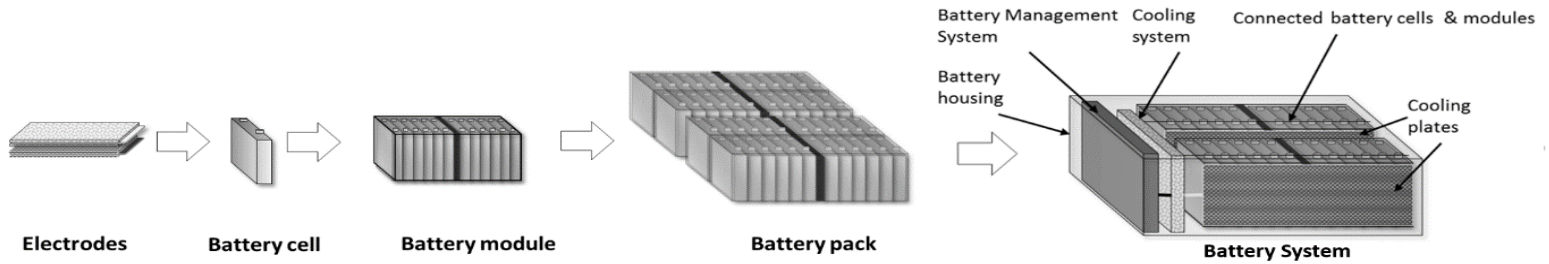
General Battery components



Lithium-ion battery components and functioning

Ref: 1) T. Hettesheimer, Strategische Produktionsplanung in jungen Märkten - Ein systemdynamischer Ansatz zur Konzeption und dynamischen Bewertung von Produktionsstrategien am Beispiel der Lithium-Ionen-Traktionsbatterie. 2017
2) Y. Nishi, "The development of lithium ion secondary batteries," Chem. Rec., vol. 1, no. 5, pp. 406–413, 2001

IMPORTANT DEFINITIONS ACCORDING TO IEC STANDARDS



Electrochemical cell / Battery cell: Electrochemical system capable of storing in chemical form the electric energy received and which can give it back by reconversion, i.e. a secondary cell (**IEC 60896-21**)

Secondary cell = …. designed to be charged electrically (= **rechargeable battery**)

Battery Module: Group of cells connected together either in a series and/or parallel configuration with or without **protective devices** (e.g. fuse or PTC) and **monitoring circuitry**. (**IEC 62620**).

Battery Pack: Energy storage device, which is comprised of one or more cells or modules electrically connected. It **may incorporate** a protective **housing** and be provided with **terminals** or other interconnection arrangement. It may include protective devices and control and monitoring, which provides information (e.g. cell voltage) to a battery system. (**IEC 62620**).

Battery System: System which incorporates one or more cells, modules, or battery packs. It has a **battery management unit** to cut off in case of overcharging, over current, and overheating. It **may have cooling or heating units**. (**IEC 62620**). Completely functional energy storage system consisting of the pack(s) and necessary ancillary subsystems for physical support, thermal management and electronic control with the thermal management system and protective circuit module respectively. (**NOTE ≠ THE CHARGER!)**

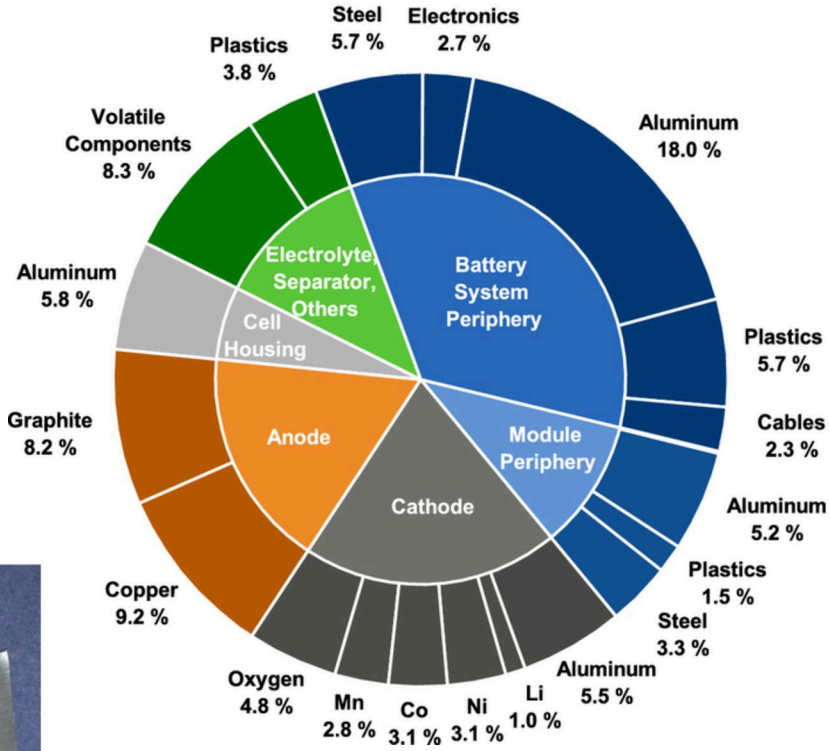
Ref: T. Hettesheimer, Strategische Produktionsplanung in jungen Märkten - Ein systemdynamischer Ansatz zur Konzeption und dynamischen Bewertung von Produktionsstrategien am Beispiel der Lithium-Ionen-Traktionsbatterie. 2017

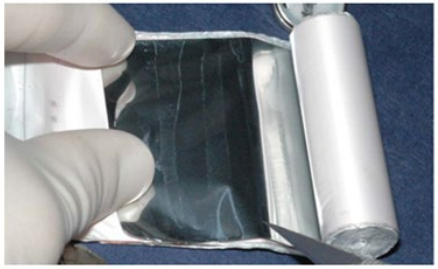
Main technology categories – overview of a main chemistries ***… To Be completed due to several remarks***

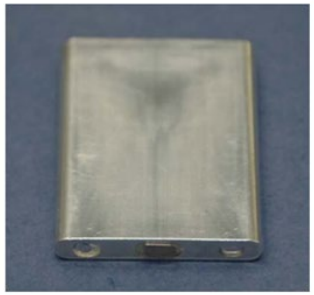
Energy Storage Technology	Electro-chemical	Primary - Secondary	Internal - External Storage	[Wh/kg] (range) @ cell level
High-energy LIB (NCA/Graphite or NMC/Graphite)	NCA/Graphite or NMC/Graphite	sec	int	200-300
Mid-energy LIB (LFP, LMO/Graphite)	LFP, LMO/Graphite	sec	int	140-200
High power LIB (LFP, NCA or NMC/Graphite, thin electrode)	LFP, NCA or NMC/Graphite	sec	int	140-200
Heavy duty LIB, high power (NMC, NCA, LFP / LTO)	NMC, NCA, LFP / LTO	sec	int	80-120
Long-life / cycle life LIB (e.g. NMC/LTO)	NMC/LTO	sec	int	80-120
Ultra high cycle life LIB (e.g. LFP/LTO)	LFP/LTO	sec	int	70-100
Lead-acid	PbO_2 / Pb	sec	int	30-45
Lead-acid sealed	PbO_2 / Pb	sec	int	30-45
NiCd	Cd / NiO_2H	sec	int	40-60
NiMH	M / $Ni(OH)_2$	sec	int	60-120
Li-primary	numerous / Li-metal	pri	int	250-700
Zn-primary	Zn / C, air	pri	int	100-450
Flywheel storage system	N/A	sec	ext	100 - 130
Compressed air storage	N/A	sec	ext	20 - 83
Pumped hydro storage	N/A	sec	ext	Unknown
Redox Flow	Vn / Vn	sec	ext	25 - 50

Main Li categories to consider – Lithium-ion chemistries, geometries and general composition

- Lithium-ion **Cobalt Oxide** (**LCO**)
- Lithium-ion **Nickel Manganese Cobalt Oxide** (**NMC**)
- Lithium-Ion **Phosphate** (**LFP**)
- Lithium-Ion **Titanate Oxide (LTO)**
- Lithium-Ion **Manganese Oxide (LMO)**
- Lithium-Ion **Manganese Nickel Oxide (LMNO)**
- Lithium **Nickel Cobalt Aluminium** (**NCA**)







Ref: J. Diekmann, C. Hanisch, L. Frob, G. Sch, T. Loellhoeffel, and A. Kwade, "Ecological Recycling of Lithium-Ion Batteries from Electric Vehicles with Focus on Mechanical Processes," vol. 164, no. 1, pp. 6184–6191, 2017. / C. Mikolajczak, M. Kahn, K. White, and R. T. Long, "Lithium-Ion Batteries Hazard and Use Assessment," no. July, 2011

PRODCOM PRODUCT CATEGORIES applicable to the study (PRODuction COMmunautaire)

The EUROPROM/Eurostat database are based on different numbers of each product that needs to be classified. The category that relates to the products investigated in this study are **all in 27.20.23 ≠ disaggregated enough to be useful for this study**

Code	Prodcom categories
27.20	Manufacture of batteries and accumulators
27.20.11	Primary cells and primary batteries
27.20.12	Parts of primary cells and primary batteries
27.20.21	Lead-acid accumulators for starting piston engines
27.20.22	Lead-acid accumulators, excluding for starting piston engines
27.20.23	**Nickel-cadmium, nickel metal hydride, lithium-ion, lithium polymer, nickel-iron and other electric accumulators**
27.20.24	Parts of electric accumulators including separators

*1Categories **according to the Battery Directive***

‘

- **Portable battery**: any battery, button cell, battery pack or accumulator that:
  - is sealed; and
  - can be hand-carried; and
  - is neither an industrial battery or accumulator nor an automotive battery.
- **automotive battery or accumulator**: any battery or accumulator used for automotive starter, lighting or ignition power;
- **industrial battery or accumulator**: any battery or accumulator designed for exclusively industrial or professional uses or used in any type of electric vehicle.

Main application categories to consider: EV = Electric Vehicle ESS = Energy Storage System

Mobile Applications
- Passenger Car (BEV, PHEV, HEV)
- Buses (BEV)
- Trucks (BEV)
- Rail (BNAT)
- Drones/Airplanes (BNAT)
- Scooter/E-bikes
- Forklifts

Other
- Information Communication Technology (ICT)
- Consumer electronics
- Cordless Power Tools (CPT)
- Uninterruptible Power Supply (UPS)

ESS
- Residential Energy Storage
- Grid Support
- Grid Energy Storage

Application categories

	Most **typical applications** (see **Task 2 on market**)															
	E-mobility applications									other				Energy Storage Systems (ESS)		
Some **typical application parameters** (See **Task 3 on use**)	Passenger Car (BEV)	Passenger Car (PHEV)	Passenger Car (HEV)	Buses (BEV)	Trucks (BEV)	Rail (BNAT)	Drones / Airplanes (BNAT)	Scooter / E-bikes	Forklift / industrial	ICT	Consumer electronics	CPT	UPS (server, lift, ..)	Residential Energy Storage	Grid support	Grid Energy storage
importance of low specific weight	high	high	high	high	high	medium	high	high	low	medium	medium	high	low	low	low	low
Importance of efficiency	high	high	high	high	high	high	high	high	high	medium	medium	medium	low	high	high	high
inportance of self discharge	medium	medium	medium	low	low	low	low	medium	low	high	high	high	high	medium	low	medium
importance of long cycle life	high	high	high	very high	high	high	high	high	high	medium	medium	medium	low	high	very high	high
Typical electrochemical battery technologies (See **Task 4 on Technologies**)																
High-energy LIB (NCA/Graphite or NMC/Graphite)	x			x		x	x	x	x	x	x	x	x	x	x	x
Mid-energy LIB (LFP, LMO/Graphite)	x			x		x		x	x	x	x	x	x	x	x	x
High power LIB (LFP, NCA or NMC/Graphite, thin electrode)		x		x		x										
Heavy duty LIB, high power (NMC, NCA, LFP / LTO)		x		x		x			x						x	
Long-life / cycle life LIB (e.g. NMC/LTO)															x	
Ultra high cycle life LIB (e.g. LFP/LTO)															x	
Lead-acid									x				x	x	x	x
Lead-acid sealed									x				x	x	x	x
NiCd		x										x				
NiMH		x									x	x				
Li-primary										x	x					
Zn-primary										x	x					

acronyms for electric vehicles(EV):	BEV = Battery Electic Vehicle, PHEV = Plug-in Electrical Vehicle, HEV = Hybrid Electric Vehicle

System boundary – see also Task 3

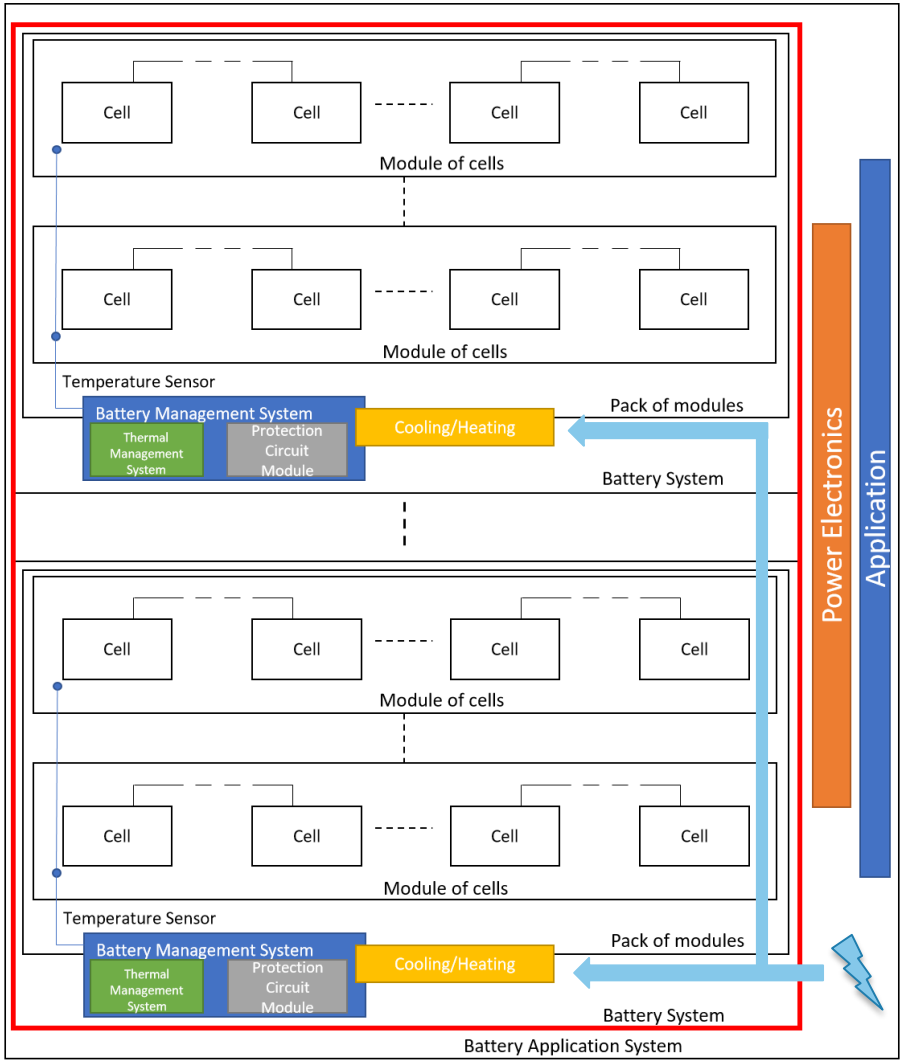
- Battery cell
- Battery module
- Battery pack
- Battery Management System (BMS)
- Cooling/Heating inside

= Battery system

- Power electronics **+ indirect charger losses**

= Battery Application system

- Heating cooling outside + **indirect energy needs for heating and cooling**



Indirect losses: Heating & Cooling / Chargers

Functional Unit (FU)

What?

the quantified performance of a product system for use as **a reference unit in life cycle assessment studies** (ISO 14040 on life cycle assessment (LCA))

Why?

Will play an important role in **Task 6 to compare improvement options**.

Which one:

- **Based on Product Environmental Footprint** (**PEF**) pilot study coordinated by the EC for '**High Specific Energy Rechargeable Batteries for Mobile Applications**' = this study for the sake of compatibility and harmonization of data
- '**functional unit (FU)**' defined as '**1 kWh (kilowatt-hour) of the total output energy delivered over the service life by the battery system (measured in kWh)'**
- Benefit of this approach is outcomes are e.g. €/kWh, CO2-eq/kWh,..

Task 1 also proposed as scope, proposal is:

***Scope*:**

The proposed scope for this study is **rechargeable industrial batteries with a high specific energy and high battery system capacity**. **for e-mobility and its second life applications??**

- An '**Industrial battery**' is defined according to the current Battery Directive (2006/66/EC). It means any **battery designed for exclusively industrial or professional uses or used in any type of electric vehicle**. The Battery Directive also includes photovoltaic **home energy storage systems** despite the category name 'industrial batteries' in this category**. Any industrial application??**

and

- '**High specific energy**' is defined by a gravimetric **energy density of typical(??) above 100 Wh/kg at cell level**

and

- '**High battery system capacity**' is defined as battery system capacity between **2 and 1000 kWh**. **and E-bike with rated capacity below 2 kWh?**

Task 1 also proposed as scope, proposal is:

How this scope was defined:

- Due **to time constraints** and in order to build on the PEF study
- **UPS** (stationary batteries) were already part of a completed **Ecodesign Study(Lot 27)** + PEF/ED Study **had a different** function and **functional unit** = providing 'power' during interrupts (≠ 'energy'), hence not compatible
- **Smaller systems** (< 2kWh) were also part of previous **Ecodesign Studies: ICT (Lot 3) and portable machine tools (Lot 5)** + portable batteries are **another category in the battery directive**
- The **large volume of LiB expected** for EV applications, see Task 2… **Task 4/5 base cases**
- Focus in Mobile applications, e-mobility = consistent with the PEF .. energy density of above 100 Wh/kg
- Applications above 1000 kWh are most often composed of multiple parallel battery systems
- Cycles complex to model(Task 3) + low volume (Task 2)
- Forlift (not density), Scooters are usually > 2 kWh, **E-bike considered low quantity?**

As a consequence:

- investigated would be **lithium-ion batteries**
- falls under '**industrial batteries' of the European Battery Directive (2006/66/EC)**
- Note that for **smaller quantity applications/products** sometimes **sensitivity analysis** are done in Task 7 to extend the scope of policy measures (in so far compatible with Task 5 model)

ED TASK 1 COMMENTS RECEIVED ON SCOPE

9 comments forms received from the stakeholders

ECOS:

- consider also Flow batteries
- clarify how UPS will be dealt with > see previous slide (Lot 27)
- **specify more about second life treatment, define the perimeter**

SAFT:

- points out that the **functional unit is only valid for mobile applications**
- **Should exclude UPS + all industrial back-up batteries** (usually, but not always, stationary), to name a few: nuclear power plants, high speed trains, airplanes, offshore platforms,

Rationale:

requirements vary widely (duration of back-up, service life, ability to withstand temperature, shock and vibrations, ability to perform additional services).

A unique functional unit would not adequately cover all these segments.

Developing use-specific functional units would require a considerable amount of resources (and would never adequately capture evolving needs).

ED TASK 1 COMMENTS RECEIVED ON SCOPE

Note some comments received from stakeholders on the scope

Recharge:

- Set energy density limit at 'typical' > 100 Wh/kg
- **Maintain the scope of "High Specific Energy Rechargeable Batteries for Mobile Applications"**

other applications cannot be assessed based on the same FU. They also have extremely diversified criteria.

NGK:

- noted some technical definitions needs to be updated related to ""batteries with internal storage" + **Ceramic Na-S or Na-NiCl2 to be added with energy density > 100 Wh/kg**

SolarpowerEurope, replied that they had no major comment.

ANEC:

- **Extend the scope** to all portable batteries, also ICT
- **At least take into account those for smaller households PV** storage and e-bikes
- Include Pb-acid batteries in the scope

Schneider (no spedific on scoping, useful input on lifetime).

Blue solutions (sent to EC Mr. Maros Sevcovic on 13/12 instead of study + 17/12 form): **add LMP batteries**

ENEL:

- **Consider all stationary** and remove 1000 KWh barrier
- Could consider flow batteries which are useful for large stationary application, look at CRM Vanadium inside

Note some comments received from stakeholders on the scope

Considering all this:

- Suggest to limit the scope to E-mobility applications and second life applications in ESS?
- Or should we also home storage? Cover which market, industry is it useful?

Please consider the state of play of Tasks 3/4:/5 t+ planning (presented this afternoon) .. to judge whether or not a scope extension is possible

-

Part on legistation

- Prior to the presentation on Standards, some words on the Ecodesign Directive (2009/125/EC):
  - Study and EC are fully aware of: 'In Article 1 on 'Subject-matter and scope' it says that it 'This Directive shall not apply to means of transport for persons or goods'.
  - .. But this should not stop us from completing Tasks 2-6 and issue policy recommendations
  - The EC is investigating possibilities to use the potential outcomes of this study (e.g. Battery Directive)

Standardisation needs under Ecodesign (battery performance)

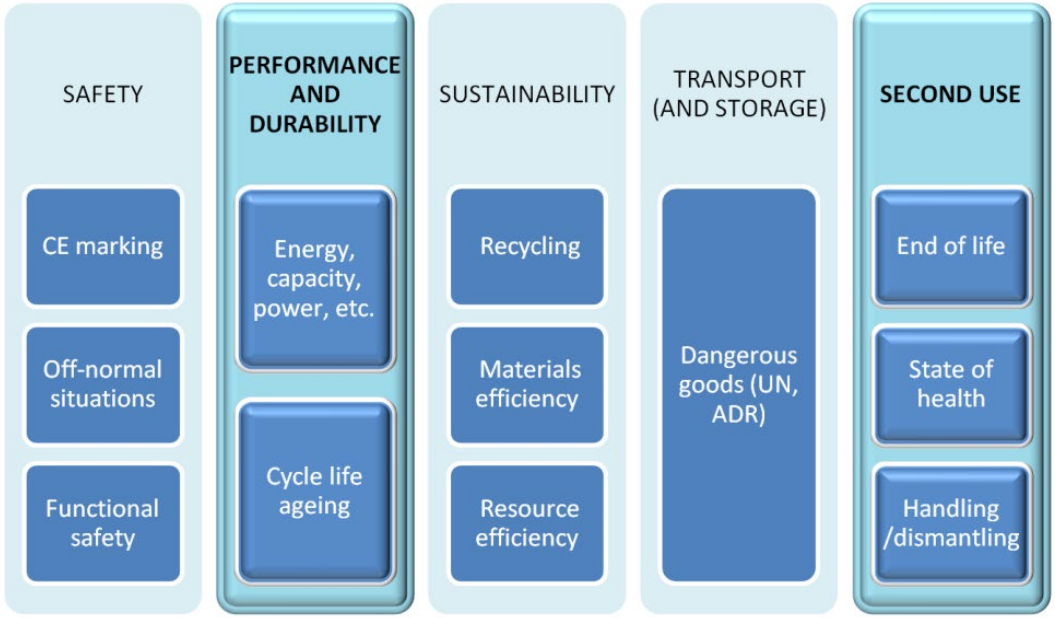
The European Commission's science and knowledge service

Joint Research Centre

European Commission

Standards for the performance and durability assessment of electric vehicle batteries

- *Traction Li-ion batteries and ecodesign*
- *Identification of needs and gaps in existing EV battery related standards*
- *Performance and durability in standards for EV battery relevant for ecodesign*
- *Second use also considered relevant*



EV traction batteries requirements considered in the report are highlighted

https://ec.europa.eu/jrc/en/publication/standards-performance-and-durability-assessment-electric-vehicle-batteries

Main identified standardisation gaps and needs

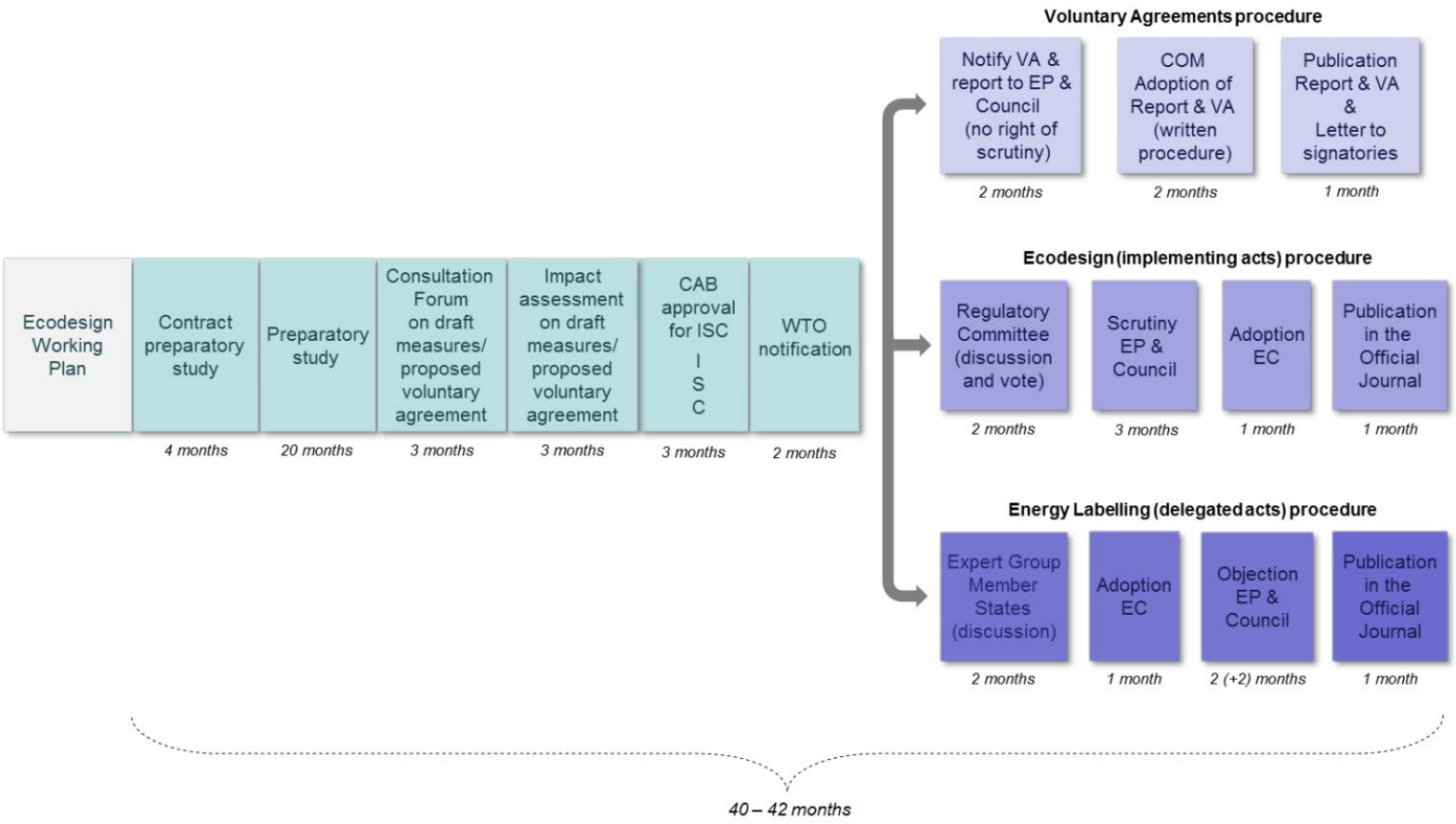
- *Define DUT (test level) and the application*
- *Chemistry oriented standards → battery performance criteria validity*
- *Clear definitions: durability, ageing, degradation, SoH, cycle life, EoL, 2nd life options (criteria, tests, protocols…)*
- *Battery durability @ real life conditions*
- *Accelerated degradation tests → battery durability under normal usage? New strategies (cost, time ⇩)*
- *Guidance and standard practices on handling, dismantlability*
- *Traceability of the battery 1st life history*
- *Safety assessment at the end of 1st use*

Standardisation process for Ecodesign

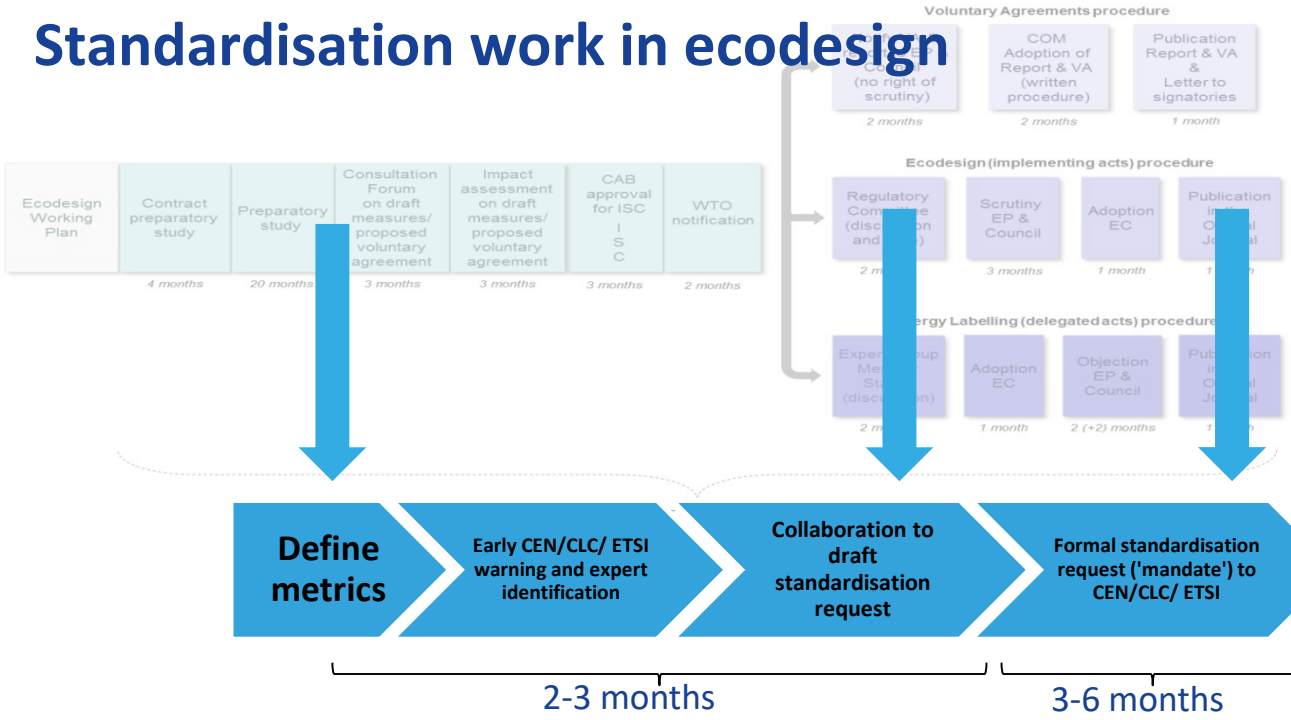
The European Commission's science and knowledge service

Joint Research Centre

European Commission



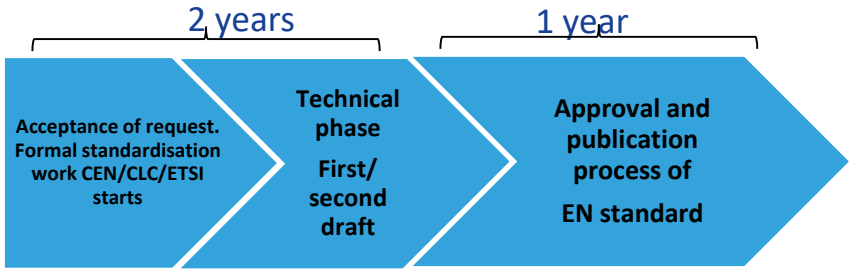
Standardisation work in ecodesign



Transitional methods **are 'pre-standards' needed only to cover possible time gap between:**

1) EN standard release

2) First application dates of the criteria



PERFORMANCE TEST STANDARDS

Overview of most relevant standards on the scope, including level and reference rate for capacity

	Reference	Chemistry	Refined application	Level	Nominal capacity
EV application	IEC 62660-1:2010	Li-ion	Cells for the propulsion of BEV	Cell	-
			Cells for the propulsion of HEV	,,	-
	ISO 12405-4:2018	Li-ion	HEV & FCV	Pack, system	1C (1 hour discharge capacity)
			BEV & PHEV	,,	1C (1 hour discharge capacity)
	DOE-INL/EXT-15-34184(2015)	Li-ion	BEV	cell to system level	C_3, including check that the capacity deviates <10% from rated capacity.
	SAE J1798:2008	-	BEV	module	-
Motorcycle	ISO/DIS 18243	Li-ion	Moped and motorcycle	pack and system	C_3 or defined by manufacturer
Industrial	IEC 62620	Li-ion	High energy (S; <C/8)	Cell up to system	C_n
			Energy (E; <C/2)	,,	C_5
			Medium rate discharge (M; <3.5C)	,,	C_5
			High rate (H; >3.5C)	,,	C_5
On-grid	IEC 61427-2	Generic	Frequency regulation service		-
			Load-following service		-
			Peak-power shaving service		-
			PV energy storage / time shift service		-
	IEC 62984-3-2:2017	Na-based	Stationary (& on-board (except propulsion))	pack, system	C_8 (8 hour discharge)
	BVES Effizienzleitfaden	Generic	PV energy storage		-

PERFORMANCE TEST STANDARDS

Overview of relevant included test topics and EOL criteria: all test methods are dissimilar

	Reference	Chemistry	Refined application	Level	Test for capacity & energy	Test for power and resistance	Energy efficiency	Storage tests	Cyclelife test	Calendar life test	EOL criterion / lifetime
EV application	IEC 62660-1:2010	Li-ion	Cells for the propulsion of BEV	Cell	x	x	x	x	x		80% of initial capacity; temperature too high
			Cells for the propulsion of HEV	,,	x	x	x	x	x		80% of initial capacity.
	ISO 12405-4:2018	Li-ion	HEV & FCV	Pack, system	x	x	x	x	x		Cycle life test conditions cannot be maintained; the parameter checks are not possible anymore; or in accordance with manufacturer.
			BEV & PHEV	,,	x	x	x	x	x		,,
	DOE-INL/EXT-15-34184(2015)	Li-ion	BEV	cell to system level	x	x		x	x	x	Dynamic stress test cycle cannot be performed within voltage limits, intended to be over 1000 DST cycles, 15 years, specific energy and power requirements.
	SAE J1798:2008	-	BEV	module	x	x		x			
Motorcycle	ISO/DIS 18243	Li-ion	Moped and motorcycle	pack and system	x	x		x	x		80% of initial capacity.
Industrial	IEC 62620	Li-ion	High energy (S; <C/8)	Cell up to system	x	x		x	x	x	Capacity > 60% after 500 cycles. Capacity >85% for standby applications.
			Energy (E; <C/2)	,,	x	x		x	x	x	,,
			Medium rate discharge (M; <3.5C)	,,	x	x		x	x	x	,,
			High rate (H; >3.5C)	,,	x	x		x	x	x	,,
On-grid	IEC 61427-2	Generic	Frequency regulation service						x		As acceptable by user
			Load-following service						x		,,
			Peak-power shaving service						x		,,
			PV energy storage / time shift service						x		,,
	IEC 62984-3-2:2017	Na-based	Stationary (& on-board (except propulsion))	pack, system	x		x	x	x		
	BVES Effizienzleitfaden	Generic	PV energy storage				x				

viegand maagøe energy people

Fraunhofer ISI

vito

Main identified standardisation gaps and needs

- *Define DUT (test level) and the application*
- *Chemistry oriented standards → battery performance criteria validity*
- *Clear definitions: durability, ageing, degradation, SoH, cycle life, EoL, 2nd life options (criteria, tests, protocols…)*
- *Battery durability @ real life conditions*
- *Accelerated degradation tests → battery durability under normal usage? New strategies (cost, time ⇩)*
- *Guidance and standard practices on handling, dismantlability*
- *Traceability of the battery 1st life history*
- *Safety assessment at the end of 1st use*