Contents of Work Package **4-WP04:** Life Cycle Analysis in Mobility Systems

4-WP04: Life Cycle Analysis in Mobility Systems

Coordinator of the WP

Czech Technical University in Prague – Faculty of Mechanical Engineering, Ing. Miroslav Žilka, Ph.D.

Participants of the WP

- you are invited

Main Goal of the WP

Creation of environmental models and subsequent processing of analyzes of the life cycle of the mobility system and its key components in the environment of the Czech Republic as a basis for quantifying environmental benefits, supporting decision-making at the level of policy formulation and innovation processes.

Partial Goals for the Current Period

Creation of Knowledge Base of LC Inputs of Key Elements of the Mobility System

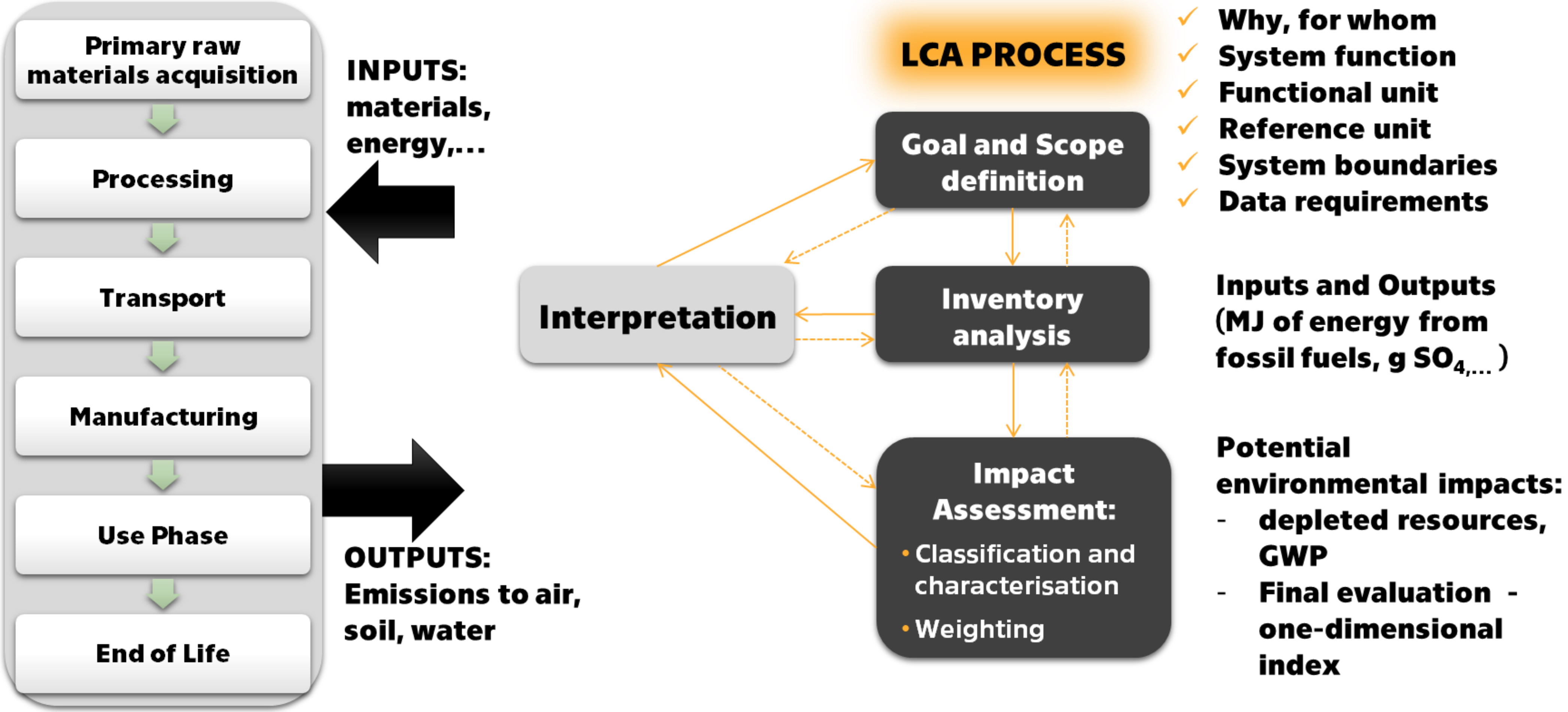
Contents of Work Package **4-WP04:** Life Cycle Analysis in Mobility Systems

4-WP04: Life Cycle Analysis in Mobility Systems

Official 4-WP04 Deliverables:

- 4-WP04-001 | **Quantitative Life Cycle Analysis of the Sustainability of the Mobility Systems and its Selected Partial Elements**, VI./2026, CTU 1.0

Activities in **4-WP04:** Life Cycle Analysis in Mobility Systems



Activities in **4-WP04:** Life Cycle Analysis in Mobility Systems

	Aktivita v DP 4-WP04	Hlavní řešitel aktivity	Doba řešení projektu			
			2023	2024	2025	2026
01	Knowledge Base of LC Inputs of Key Elements of the Mobility System	Miroslav Žilka, Barbora Stieberová (FS ČVUT)	ano	ano	ne	ne
02	Definition of Scenarios, Structure of the Environmental Model, Catalog of Process Flowcharts of Key Components of the Mobility System	Miroslav Žilka, Barbora Stieberová (FS ČVUT)	ne	ano	ano	ne
03	Environmental Analysis of the Mobility System in the Czech Republic and its Key Components	Miroslav Žilka, Barbora Stieberová (FS ČVUT)	ne	ne	ano	ano
04	Identification of Case Studies within the Consortium for the Processing of LC Analyses	Miroslav Žilka, Barbora Stieberová (FS ČVUT)	ne	ano	ano	ne
05	Case Studies LC Analyses	Miroslav Žilka, Barbora Stieberová (FS ČVUT)	ne	ne	ano	ano

Activities in **4-WP04:** Life Cycle Analysis in Mobility Systems

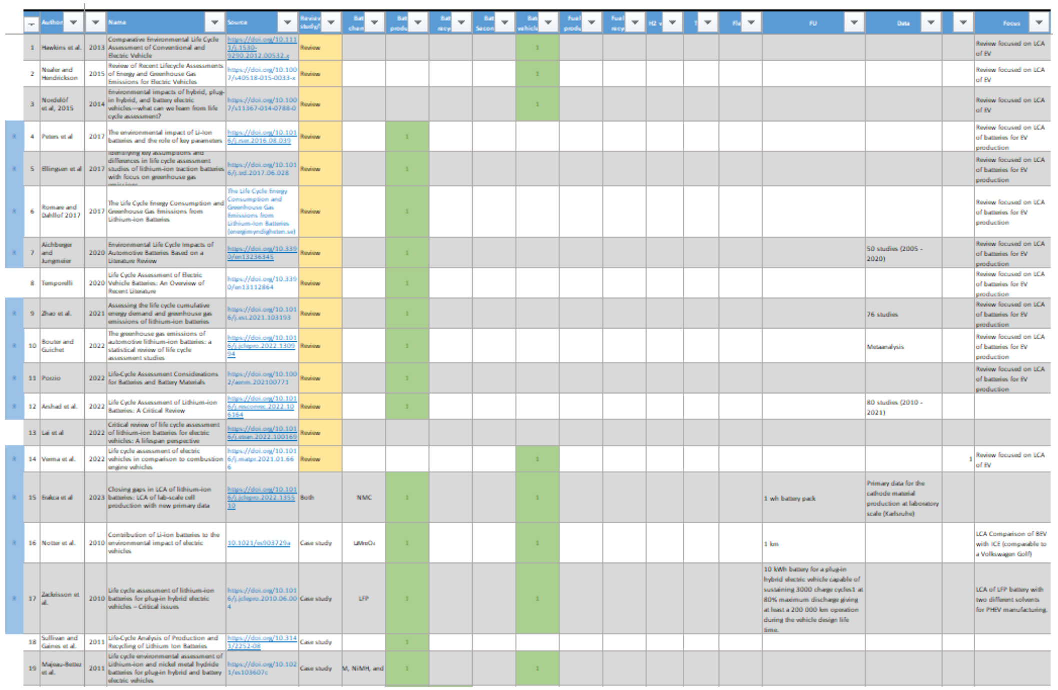
Activity	**Knowledge Base of LC Inputs of Key Elements of the Mobility System**
Time of realization	04/2023 – 06/2024
Output	**4-WP04-001 (O):** Quantitative Life Cycle Analysis of the Sustainability of the Mobility Systems and its Selected Partial Elements (FS ČVUT) **6/2026**

Activity outputs:

1. Structuralized database of relevant information sources
2. Report summarizing main findings and insights from the review

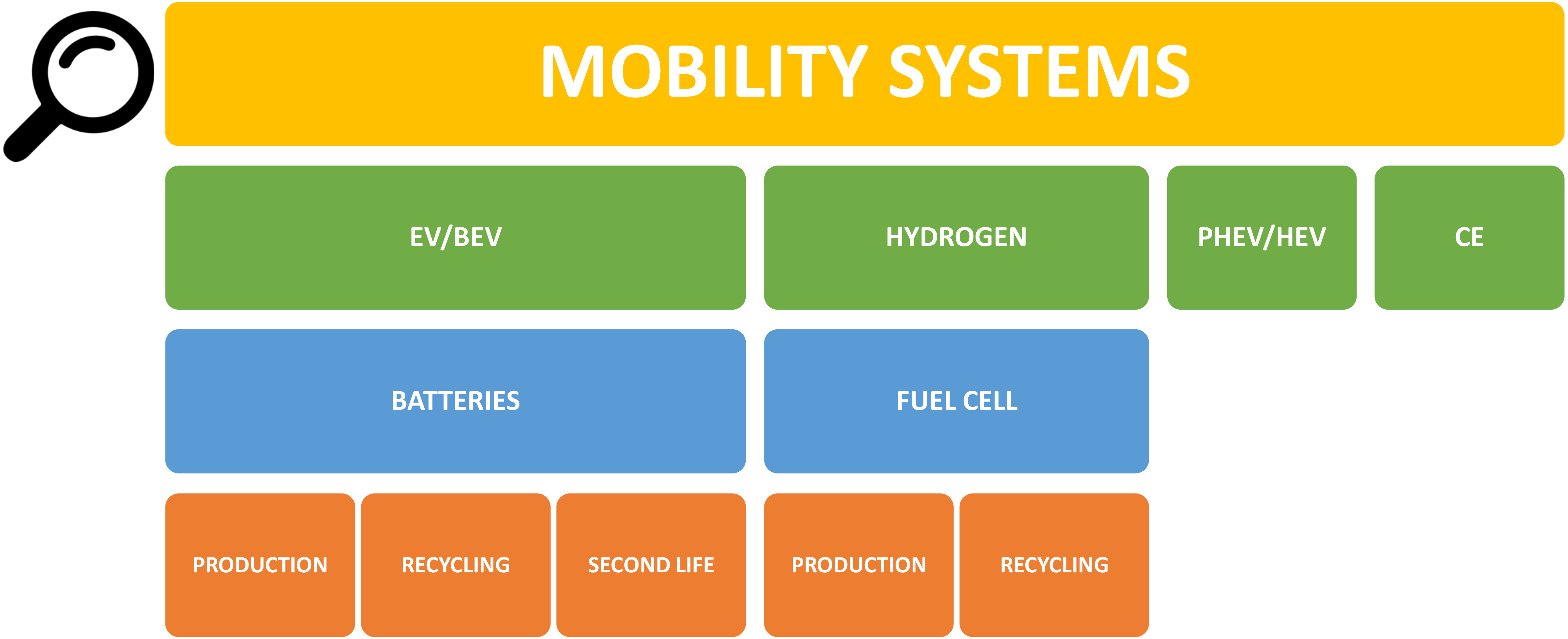
Why?

- Capturing the current state of knowledge in the field of LCA analyzes of key elements of the mobility system
- Obtaining inputs for LC modelling
- Building a knowledge base for the consortium



Activities in **4-WP04:** Life Cycle Analysis in Mobility Systems

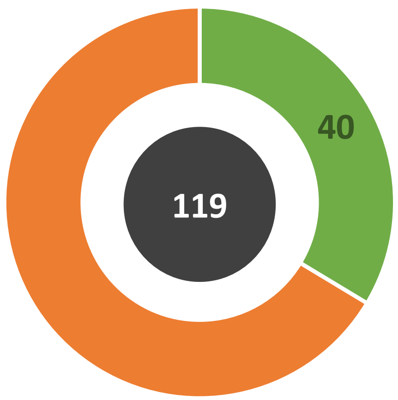
Knowledge Base of LC Inputs of Key Elements of the Mobility System



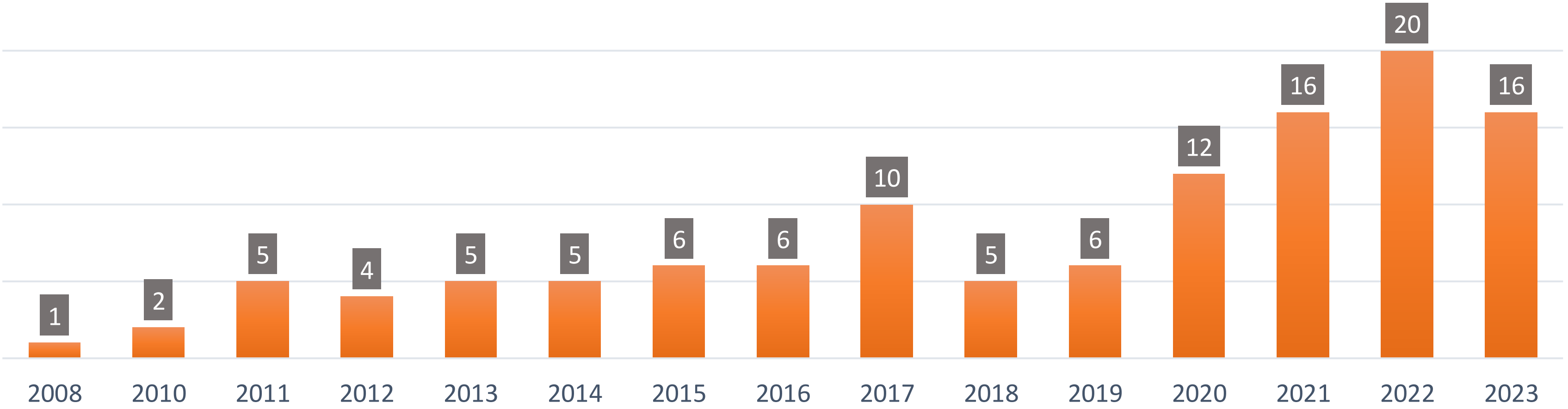
Activities in **4-WP04:** Life Cycle Analysis in Mobility Systems

Knowledge Base of LC Inputs of Key Elements of the Mobility System

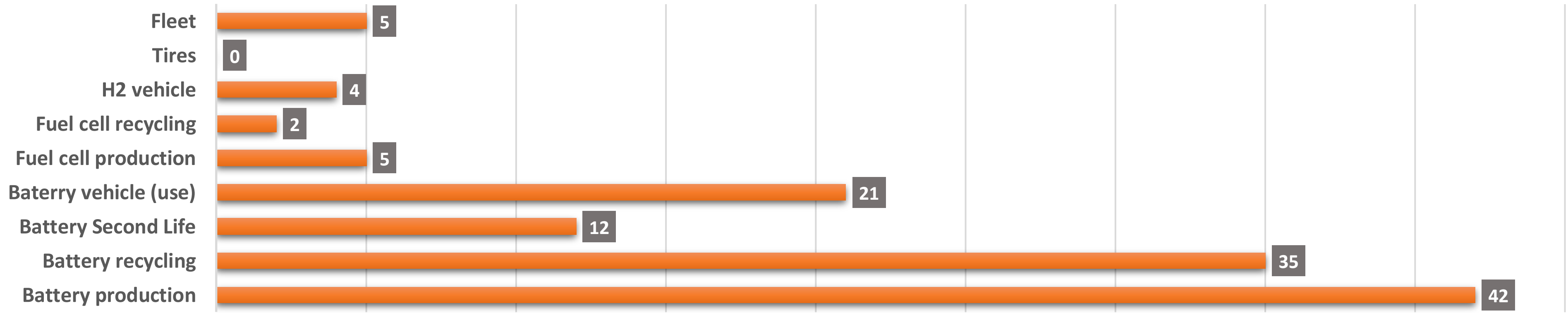
TOTAL NO. OF LC STUDIES (10/2023)



No. of studies in time (2008 – 09/2023)



FOCUS OF LC STUDIES



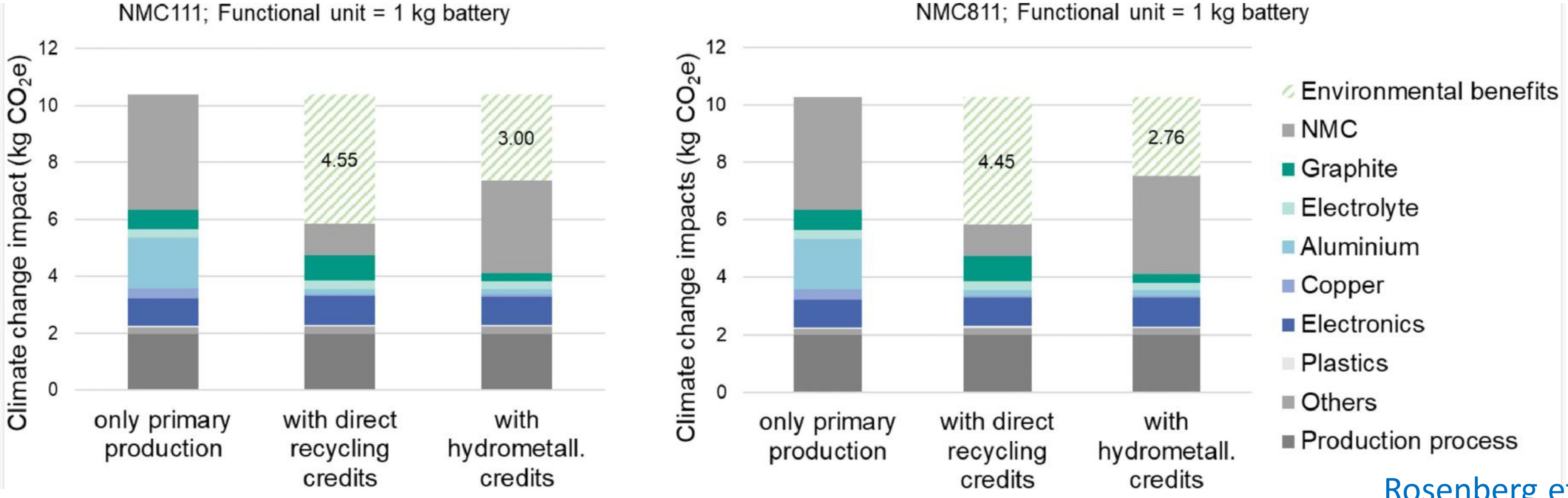
Activities in **4-WP04:** Life Cycle Analysis in Mobility Systems

Knowledge Base of LC Inputs of Key Elements of the Mobility System

- **Preliminary general conclusions:**

There **is an intense developement of recycling processes** in the recent years and new LCA studies can be found: e.g. Mohr et al, 2020, Zhou 2020, Kallitsis 2022, Adhikari, 2023, Rosenberg, 2023, and also review papers: Pražanová 2022, Li 2023.

e.g. Rosenberg et al, 2023 show the GWP benefits of direct recycling in comparison with advanced hydrometallurgical process (grade material).



Rosenberg et al, 2023

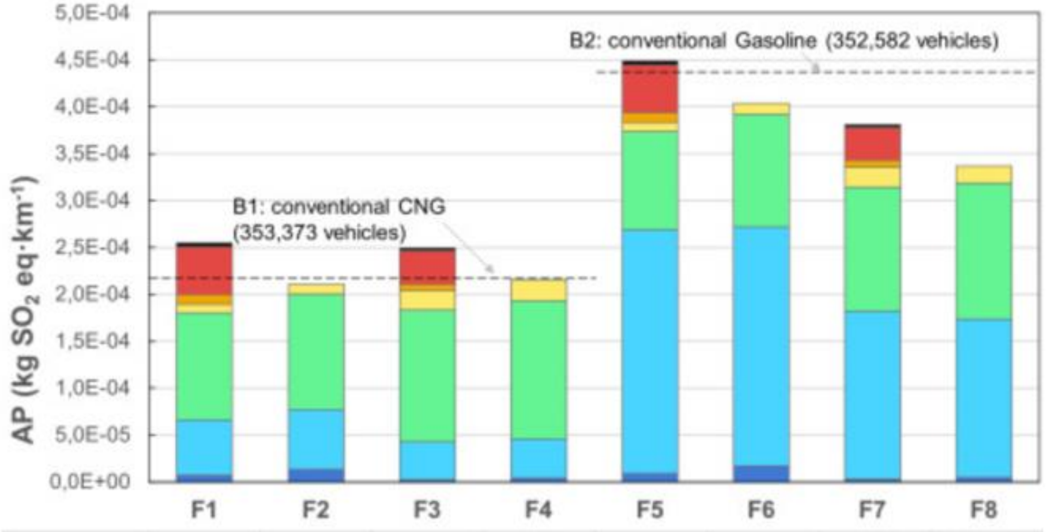
Activities in **4-WP04:** Life Cycle Analysis in Mobility Systems

Knowledge Base of LC Inputs of Key Elements of the Mobility System

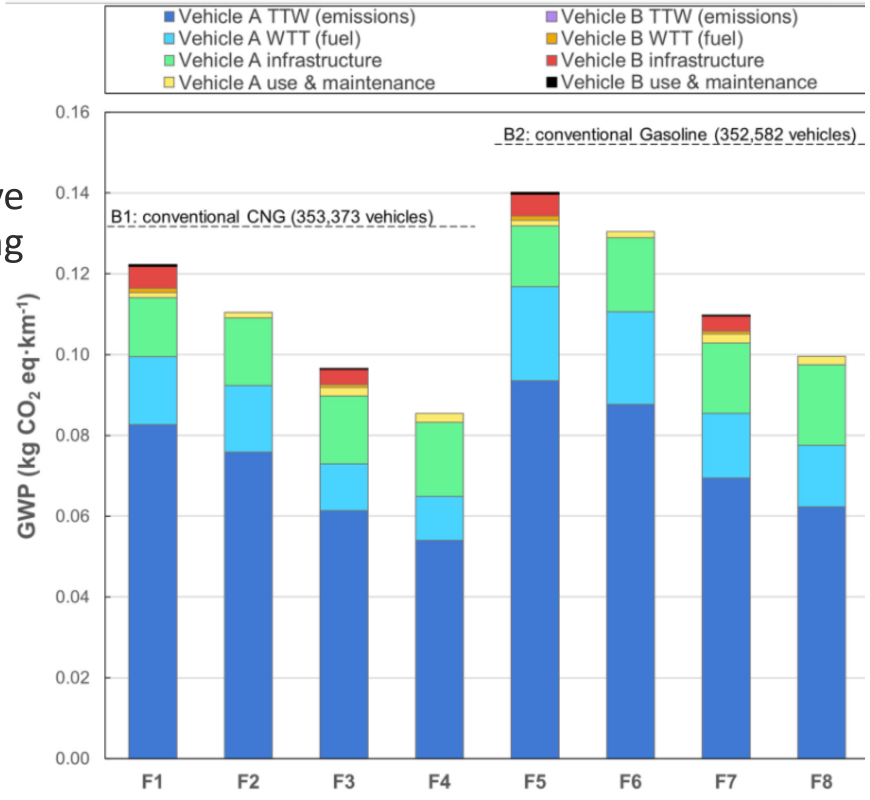
- **Preliminary general conclusions:**

Transition strategies

- Tarabay et al. 2023 show that 100% of new LDV sales being PHEV by 2029 would have equivalent cumulative (2020–2050) life cycle GHG emissions as 100% new sales being BEV by 2035
- Candelaresi, 2023 the use of hydrogen blends could facilitate the transition towards an environmentally sustainable transport



8 different fleets with H2 in Italy

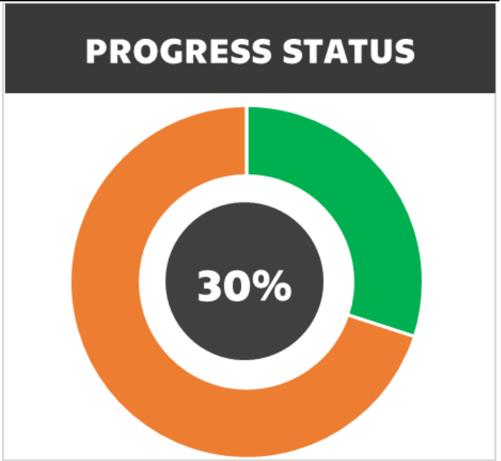


	F1	F2	F3	F4	F5	F6	F7	F8
Number of Vehicle A	CNG 327,486	Hythane 397,178	HEV CNG 496,190	HEV Hythane 601,785	Gasoline 326,752	H_2-Gasoline 395,194	HEV Gasoline 495,080	HEV H_2-Gasoline 598,779
Number of Vehicle B	FCEV 46,305	-	FCEV 46,305	-	FCEV 46,305	-	FCEV 46,305	-
Total vehicle number	373,791	397,178	542,495	601,785	373,057	395,194	541,385	598,779

Fulfillment of goals and deliverables of **4-WP04:** Life Cycle Analysis in Mobility Systems

Current State of Deliverables, Milestones and Fulfillment of Goals

M: Knowledge Base of LC Inputs of Key Elements of the Mobility System (06/2024)



List of Due Deliverables and Their Added Value

4-WP04-001 (O): Quantitative Life Cycle Analysis of the Sustainability of the Mobility Systems and its Selected Partial Elements

- Work on the first milestone towards the processing of the deliverable
- **WiP & no major delays**

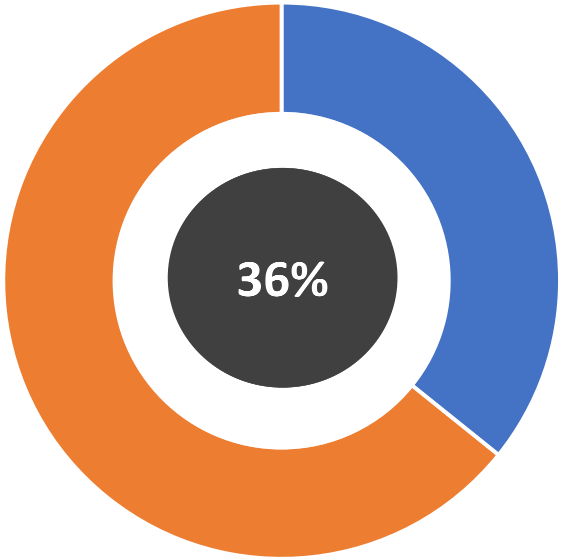
Current contribution of **4-WP04:** Life Cycle Analysis in Mobility Systems

Assessment of the Contribution of Deliverables

- Building a structured knowledge base in the field of LC studies of mobility systems and its sub-elements for the use of consortium members.
- Presentation of benefits and data structure of LC analyses, identification of suitable case studies within the consortium.

Current contribution of **4-WP04:** Life Cycle Analysis in Mobility Systems

Assessment of the Formal/Administrative Goals of the Work Package

Finances	Commercialisation	Deliverables
BUDGET CONSUMPTION 04-09 2023 	Analytical tasks M Not relevant	OK

Current contribution of **4-WP04:** Life Cycle Analysis in Mobility Systems

Acknowledgment

This research has been realized using the support of Technological Agency, Czech Republic, programme National Competence Centres II, project # TN02000054 Božek Vehicle Engineering National Center of Competence (BOVENAC).

4-WP04: Life Cycle Analysis in Mobility Systems

Thank you for your attention

ANY QUESTIONS?

Miroslav Žilka	Miroslav.zilka@fs.cvut.cz	+420 603 279 144

Výtah z prací 2023-2025 na **4-WP04:** Analýzy životního cyklu v systémech mobility

Ing. Miroslav Žilka, Ph.D. (ČVUT – FS) – miroslav.zilka@fs.cvut.cz

Z důvodu vysoké náročnosti na rozsah vstupních dat bude prvním krokem vytvoření znalostní báze pro tvorbu LC analýz. Jejím účelem je samozřejmě zajištění potřebných vstupů pro tvorbu environmentálních modelů, ale předpokládáme, že bude ve formě strukturované databáze informačních zdrojů k dispozici všem členům konsorcia. Kromě strukturované databáze bude výstupem tohoto kroku souhrnná zpráva, která bude zachycovat klíčové informace komplexní rešerše.

V dalším kroku budou definovány jednotlivé klíčové komponenty systému mobility v podobě flow-chartů zachycujících klíčové jednotkové procesy a vstupní parametry. Rovněž budou definovány scénáře budoucího vývoje.

Následně bude sestaven environmentální model v systému SimaPro a s jeho pomocí bude provedena analýza systému mobility a jejich klíčových komponent v prostředí České republiky. Výstup této analýzy by měl mís podobu souhrnné zprávy.

Především ve druhé polovině sledovaného období by rovněž měly být v rámci konsorcia identifikovány vhodné case studies (konkrétní inovační projekty), pro zpracování dílčí LC analýz.

Results of **4-WP04:** Life Cycle Analysis in Mobility Systems – Achieved 2023-2025

Ing. Miroslav Žilka, Ph.D. (ČVUT – FS) – miroslav.zilka@fs.cvut.cz

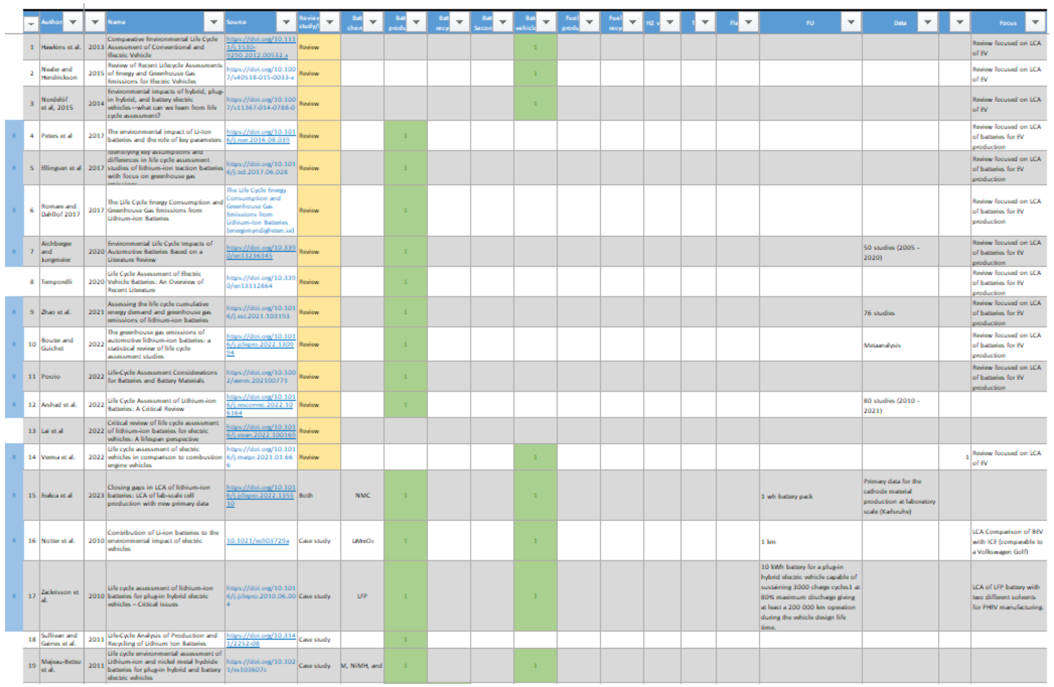
Due to the high demands on the range of input data, the first step will be the creation of a knowledge base for the creation of LC analyses. Its purpose is, of course, to provide the necessary inputs for the creation of environmental models, but we assume that it will be available to all members of the consortium in the form of a structured database of information resources. In addition to the structured database, the output of this step will be a summary report that will capture the key information of the complex search. In the next step, individual key components of the mobility system will be defined in the form of flow-charts capturing key unit processes and input parameters. Future development scenarios will also be defined. Subsequently, an environmental model will be compiled in the SimaPro system and with its help an analysis of the mobility system and its key components in the environment of the Czech Republic will be carried out. The output of this analysis should take the form of a summary report.

Especially in the second half of the period, suitable case studies (specific innovation projects) should also be identified within the consortium, for the processing of partial LC analyses.

Výtah z prací 2023 na **4-WP04:** Analýzy životního cyklu v systémech mobility

Ing. Miroslav Žilka, Ph.D. (ČVUT – FS) – miroslav.zilka@fs.cvut.cz

V roce 2023 byly započaty práce na tvorbě znalostní báze. Primárně byla navržena její struktura umožňující filtraci zdrojů dle tematického a obsahového zamření. Dále byly akumulovány informační zdroje zaměřené na LC studie (v současnosti více jak 120 zdrojů) v oblasti mobility. Ty jsou průběžně zpracovávány a analyzovány. Klíčové informace jsou integrovány do souhrnného reportu, který by měl být finalizován v polovině roku 2024.



		Author		Name	Source	Review study/	Bat chem	Bat produ	Bat recy	Bat Secon	Bat vehicle	Fuel produ	Fuel recy	H2 v	T	Fle	FU	Data		Focus
	1	Hawkins et al.	2013	Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicle	https://doi.org/10.1111/j.1530-9290.2012.00532.x	Review					1									Review focused on LCA of EV
	2	Nealer and Hendrickson	2015	Review of Recent Lifecycle Assessments of Energy and Greenhouse Gas Emissions for Electric Vehicles	https://doi.org/10.1007/s40518-015-0033-x	Review					1									Review focused on LCA of EV
	3	Nordelöf et al, 2015	2014	Environmental impacts of hybrid, plug-in hybrid, and battery electric vehicles—what can we learn from life cycle assessment?	https://doi.org/10.1007/s11367-014-0788-0	Review					1									Review focused on LCA of EV
R	4	Peters et al	2017	The environmental impact of Li-Ion batteries and the role of key parameters	https://doi.org/10.1016/j.rser.2016.08.039	Review		1												Review focused on LCA of batteries for EV production
R	5	Ellingsen et al	2017	Identifying key assumptions and differences in life cycle assessment studies of lithium-ion traction batteries with focus on greenhouse gas emissions	https://doi.org/10.1016/j.trd.2017.06.028	Review		1												Review focused on LCA of batteries for EV production
R	6	Romare and Dahllöf 2017	2017	The Life Cycle Energy Consumption and Greenhouse Gas Emissions from Lithium-Ion Batteries	The Life Cycle Energy Consumption and Greenhouse Gas Emissions from Lithium-Ion Batteries (energimyndigheten.se)	Review		1												Review focused on LCA of batteries for EV production
R	7	Aichberger and Jungmeier	2020	Environmental Life Cycle Impacts of Automotive Batteries Based on a Literature Review	https://doi.org/10.3390/en13236345	Review		1										50 studies (2005 - 2020)		Review focused on LCA of batteries for EV production
	8	Temporelli	2020	Life Cycle Assessment of Electric Vehicle Batteries: An Overview of Recent Literature	https://doi.org/10.3390/en13112864	Review		1												Review focused on LCA of batteries for EV production
R	9	Zhao et al.	2021	Assessing the life cycle cumulative energy demand and greenhouse gas emissions of lithium-ion batteries	https://doi.org/10.1016/j.est.2021.103193	Review		1										76 studies		Review focused on LCA of batteries for EV production
R	10	Bouter and Guichet	2022	The greenhouse gas emissions of automotive lithium-ion batteries: a statistical review of life cycle assessment studies	https://doi.org/10.1016/j.jclepro.2022.130994	Review		1										Metaanalysis		Review focused on LCA of batteries for EV production
R	11	Porzio	2022	Life-Cycle Assessment Considerations for Batteries and Battery Materials	https://doi.org/10.1002/aenm.202100771	Review		1												Review focused on LCA of batteries for EV production
R	12	Arshad et al.	2022	Life Cycle Assessment of Lithium-ion Batteries: A Critical Review	https://doi.org/10.1016/j.resconrec.2022.106164	Review		1										80 studies (2010 - 2021)		
	13	Lai et al	2022	Critical review of life cycle assessment of lithium-ion batteries for electric vehicles: A lifespan perspective	https://doi.org/10.1016/j.etran.2022.100169	Review														
R	14	Verma et al.	2022	Life cycle assessment of electric vehicles in comparison to combustion engine vehicles	https://doi.org/10.1016/j.matpr.2021.01.666	Review					1								1	Review focused on LCA of EV
R	15	Erakca et al	2023	Closing gaps in LCA of lithium-ion batteries: LCA of lab-scale cell production with new primary data	https://doi.org/10.1016/j.jclepro.2022.135510	Both	NMC	1			1						1 wh battery pack	Primary data for the cathode material production at laboratory scale (Karlsruhe)		
R	16	Notter et al.	2010	Contribution of Li-ion batteries to the environmental impact of electric vehicles	10.1021/es903729a	Case study	$LiMn_2O_4$	1			1						1 km			LCA Comparison of BEV with ICE (comparable to a Volkswagen Golf)
R	17	Zackrisson et al.	2010	Life cycle assessment of lithium-ion batteries for plug-in hybrid electric vehicles – Critical issues	https://doi.org/10.1016/j.jclepro.2010.06.004	Case study	LFP	1			1						10 kWh battery for a plug-in hybrid electric vehicle capable of sustaining 3000 charge cycles1 at 80% maximum discharge giving at least a 200 000 km operation during the vehicle design life time.			LCA of LFP battery with two different solvents for PHEV manufacturing.
	18	Sullivan and Gaines et al.	2011	Life-Cycle Analysis of Production and Recycling of Lithium Ion Batteries	https://doi.org/10.3141/2252-08	Case study		1												
	19	Majeau-Bettez et al.	2011	Life cycle environmental assessment of Lithium-ion and nickel metal hydride batteries for plug-in hybrid and battery electric vehicles	https://doi.org/10.1021/es103607c	Case study	M, NiMH, and	1			1									

Databáze informačních zdrojů

Results of **4-WP04:** Life Cycle Analysis in Mobility Systems – Achieved 2023

Ing. Miroslav Žilka, Ph.D. (ČVUT – FS) – miroslav.zilka@fs.cvut.cz

In 2023, work began on the creation of a knowledge base. Its structure was primarily designed to enable the filtering of sources according to thematic and content focus. Furthermore, information resources focused on LC studies in the field of mobility were accumulated (currently more than 120 resources). These are continuously processed and analyzed. Key information is integrated into a summary report, which should be finalized in mid-2024.

		Author		Name	Source	Review study/	Bat chem	Bat produ	Bat recy	Bat Secon	Bat vehicl	Fuel produ	Fuel recy	H2 v	T	Fle	FU	Data		Focus
	1	Hawkins et al.	2013	Comparative Environmental Life Cycle Assessment of Conventional and Electric Vehicle	https://doi.org/10.1111/j.1530-9290.2012.00532.x	Review					1									Review focused on LCA of EV
	2	Nealer and Hendrickson	2015	Review of Recent Lifecycle Assessments of Energy and Greenhouse Gas Emissions for Electric Vehicles	https://doi.org/10.1007/s40518-015-0033-x	Review					1									Review focused on LCA of EV
	3	Nordelöf et al, 2015	2014	Environmental impacts of hybrid, plug-in hybrid, and battery electric vehicles—what can we learn from life cycle assessment?	https://doi.org/10.1007/s11367-014-0788-0	Review					1									Review focused on LCA of EV
R	4	Peters et al	2017	The environmental impact of Li-Ion batteries and the role of key parameters	https://doi.org/10.1016/j.rser.2016.08.039	Review		1												Review focused on LCA of batteries for EV production
R	5	Ellingsen et al	2017	Identifying key assumptions and differences in life cycle assessment studies of lithium-ion traction batteries with focus on greenhouse gas emissions	https://doi.org/10.1016/j.trd.2017.06.028	Review		1												Review focused on LCA of batteries for EV production
R	6	Romare and Dahllof 2017	2017	The Life Cycle Energy Consumption and Greenhouse Gas Emissions from Lithium-ion Batteries	The Life Cycle Energy Consumption and Greenhouse Gas Emissions from Lithium-Ion Batteries (energimyndigheten.se)	Review		1												Review focused on LCA of batteries for EV production
R	7	Aichberger and Jungmeier	2020	Environmental Life Cycle Impacts of Automotive Batteries Based on a Literature Review	https://doi.org/10.3390/en13236345	Review		1										50 studies (2005 - 2020)		Review focused on LCA of batteries for EV production
	8	Temporelli	2020	Life Cycle Assessment of Electric Vehicle Batteries: An Overview of Recent Literature	https://doi.org/10.3390/en13112864	Review		1												Review focused on LCA of batteries for EV production
R	9	Zhao et al.	2021	Assessing the life cycle cumulative energy demand and greenhouse gas emissions of lithium-ion batteries	https://doi.org/10.1016/j.est.2021.103193	Review		1										76 studies		Review focused on LCA of batteries for EV production
R	10	Bouter and Guichet	2022	The greenhouse gas emissions of automotive lithium-ion batteries: a statistical review of life cycle assessment studies	https://doi.org/10.1016/j.jclepro.2022.130994	Review		1										Metaanalysis		Review focused on LCA of batteries for EV production
R	11	Porzio	2022	Life-Cycle Assessment Considerations for Batteries and Battery Materials	https://doi.org/10.1002/aenm.202100771	Review		1												Review focused on LCA of batteries for EV production
R	12	Arshad et al.	2022	Life Cycle Assessment of Lithium-ion Batteries: A Critical Review	https://doi.org/10.1016/j.resconrec.2022.106164	Review		1										80 studies (2010 - 2021)		
	13	Lai et al	2022	Critical review of life cycle assessment of lithium-ion batteries for electric vehicles: A lifespan perspective	https://doi.org/10.1016/j.etran.2022.100169	Review														
R	14	Verma et al.	2022	Life cycle assessment of electric vehicles in comparison to combustion engine vehicles	https://doi.org/10.1016/j.matpr.2021.01.666	Review					1								1	Review focused on LCA of EV
R	15	Erakca et al	2023	Closing gaps in LCA of lithium-ion batteries: LCA of lab-scale cell production with new primary data	https://doi.org/10.1016/j.jclepro.2022.135510	Both	NMC	1			1						1 wh battery pack	Primary data for the cathode material production at laboratory scale (Karlsruhe)		
R	16	Notter et al.	2010	Contribution of Li-ion batteries to the environmental impact of electric vehicles	10.1021/es903729a	Case study	LiMn₂O₄	1			1						1 km			LCA Comparison of BEV with ICE (comparable to a Volkswagen Golf)
R	17	Zackrisson et al.	2010	Life cycle assessment of lithium-ion batteries for plug-in hybrid electric vehicles – Critical issues	https://doi.org/10.1016/j.jclepro.2010.06.004	Case study	LFP	1			1						10 kWh battery for a plug-in hybrid electric vehicle capable of sustaining 3000 charge cycles1 at 80% maximum discharge giving at least a 200 000 km operation during the vehicle design life time.			LCA of LFP battery with two different solvents for PHEV manufacturing.
	18	Sullivan and Gaines et al.	2011	Life-Cycle Analysis of Production and Recycling of Lithium Ion Batteries	https://doi.org/10.3141/2252-08	Case study		1												
	19	Majeau-Bettez et al.	2011	Life cycle environmental assessment of Lithium-ion and nickel metal hydride batteries for plug-in hybrid and battery electric vehicles	https://doi.org/10.1021/es103607c	Case study	M, NiMH, and	1			1									

Database of information sources