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FROM ENERGY EFFICIENCY TO CIRCULARITY, THE CASE OF PUBLIC TRANSPORT

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Summary

An innovative analysis to support strategic decisions for the fleet in public transport (TCRO)

https://www.enelfoundation.org/topics/articles/20210/11/scenarios-and-prospects-of-electrification-of-public-road-transp

Facilitate transitioning to circular economy in Public Transport

https://www.interreg-central.eu/projects/ce4ce/

Context of the research and general objectives

The objective of the study is to **develop a systemic benchmark analysis among different management models and power supply alternatives**, to better understand scenarios and perspectives of the electrification of public road transport in 2021, 2025 and 2030. The **"Total costs and revenues of ownership" (TCRO)** will be adopted, focusing on standard 12-meter buses dedicated to urban transport.

Analyzed motorizations at different time scenarios (2021, 2025 e 2030) are the following:

- Diesel
- CNG-LNG e biomethane
- Elettric
- Hydrogen

In order to adopt a systemic vision exernal elements other than the pure TCRO approach, expected to influence the choices of public transport operators in terms of bus engines have been highlighted. In particular the following elements have been considered:

- **Policy:** procurement obligations stated by EU regulations and other national directives, but also strategic choices by public transport companies shareholders (e.g. Public bodies especially sensitive to sustainability aspects).
- **Technological:** infrastructure investment costs necessary for the deployment of alternative fuel based motorizations (charging, depots, etc.), requiring economies of scale and availability of space (e.g. for dedicated depots, charging facilities / alternative fuel plants).
- **Organizational**: specific carachteristics of the lines (elevation profiles, length or climate conditions).

The components of the TCRO

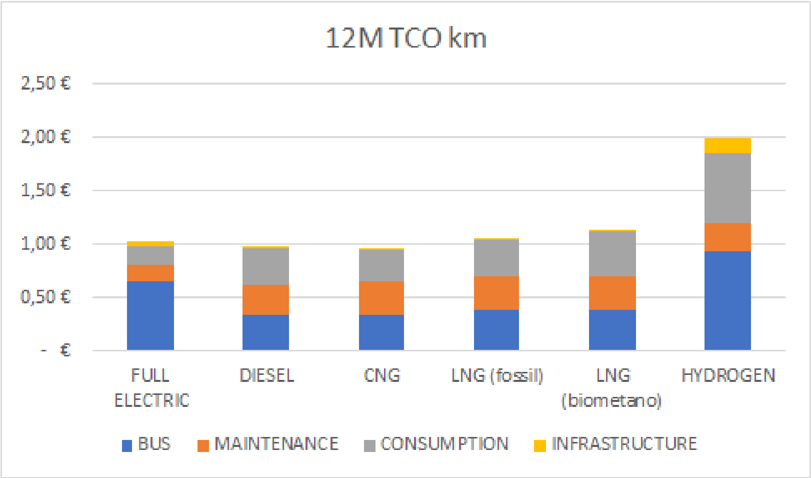
COMPANY COST COMPONENTS	
Capex	*Opex*
Initial bus and infrastructure (depots and termini) purchasing costs	Energy cost for traction
	Ordinary bus maintenance
	Extraordinaly bus maintenance
	Infrastructure maintenance
COMPANY REVENUE COMPONENTS	
Revenues from assets sales	*Revenues from grid revenues*
End-of life battery value	Bus2Grid
SOCIAL COST COMPONENTS	
Environmental externalities: local pollutants, GHG emissions, noise pollution	

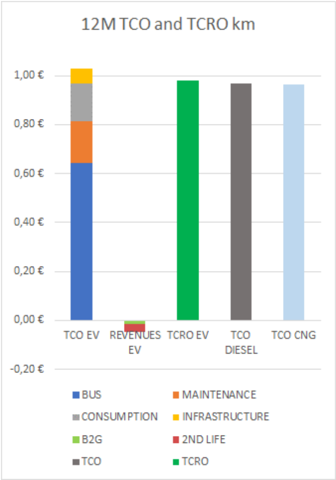
Source: GREEN elaborations on Grauers et al. (2020), World Bank (2019) and TOI - Institute of Transport Economics (2018)

Environmental externalities have not been economically quantified, as they would require specific in-depth analysis beyond the scope of the study. In case environmental externalities would be considered, this would further improve the economic convenience of electric motorizations.
This would result, in lower thresholds in terms minimum mileages required to reach the economic break-even than the ones presented in the analysis.

Costs and revenues by component for 12M, year 2021

	FULL ELECTRIC	DIESEL	CNG	LNG (fossil)	LNG (biometano)	HYDROGEN
BUS	0,642 €	0,334 €	0,343 €	0,379 €	0,379 €	0,923 €
MAINTENANCE	0,170 €	0,289 €	0,310 €	0,310 €	0,310 €	0,273 €
CONSUMPTION	0,158 €	0,341 €	0,297 €	0,353 €	0,433 €	0,661 €
INFRASTRUCTURE	0,058 €	0,003 €	0,014 €	0,007 €	0,007 €	0,130 €
B2G	0,0153 €					
2ND LIFE	0,0327 €					
Total TCO	1,028 €	0,968 €	0,963 €	1,049 €	1,129 €	1,986 €
Total TCRO	0,979 €	0,968 €	0,963 €	1,049 €	1,129 €	1,986 €





GREEN elaborations, year 2021

Break-even according to TCRO approach

TCO and TCRO: break-even price for 12M e-bus compared to Diesel and CNG, 2021

TCO

	Break even price	diff. current price	diff. %
vs DIESEL	390.888,63 €	- 49.111,37 €	-11,16%
vs CNG	386.763,63 €	- 53.236,37 €	-12,10%

TCRO

	Break even price	diff. current price	diff. %
vs DIESEL	430.545,97 €	- 9.454,03 €	-2,15%
vs CNG	426.420,97 €	- 13.579,03 €	-3,09%

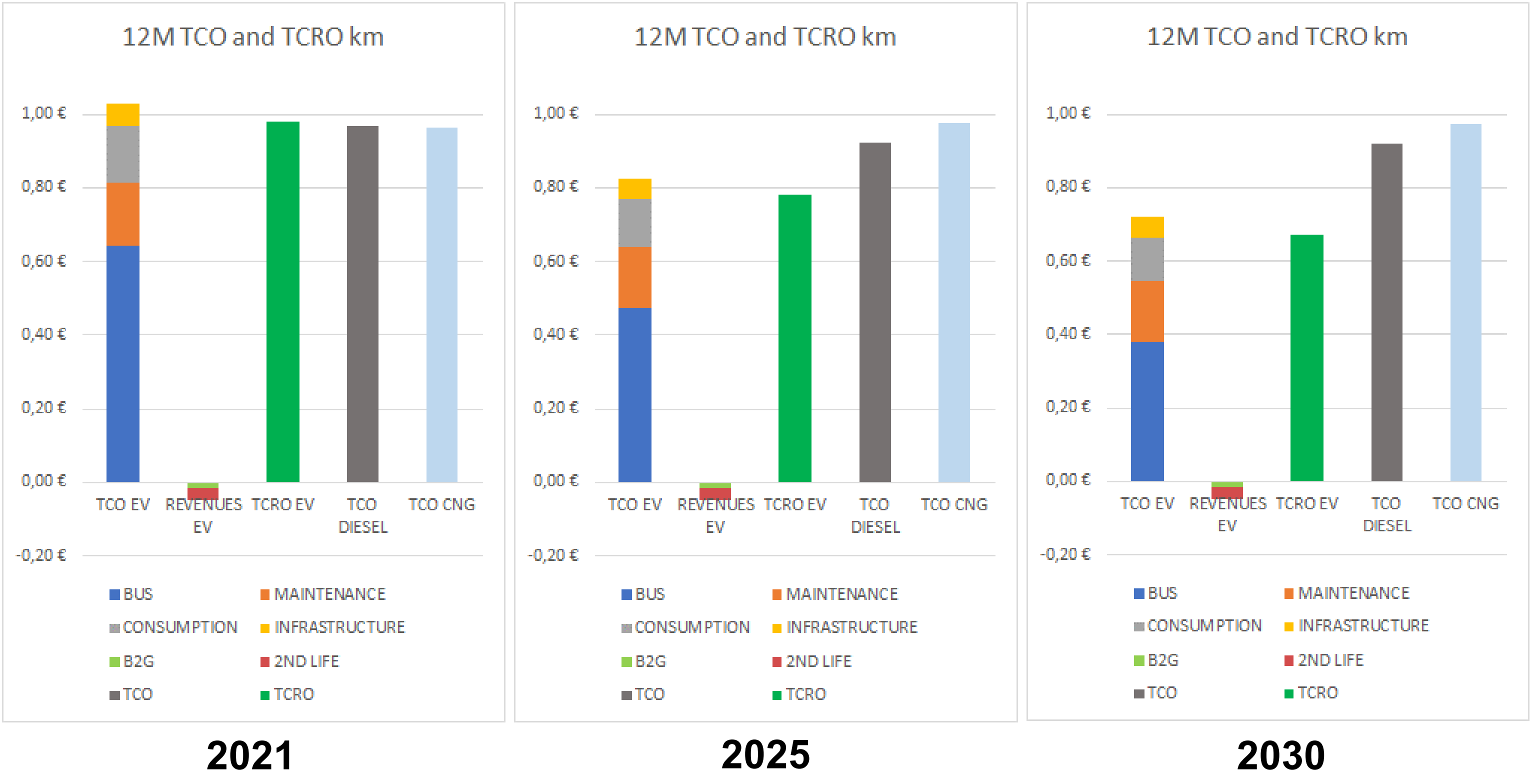
GREEN elaborations, year 2021

Confirming the importance of the contribution of revenues to the economic sustainability of the electrification of LPT fleets, the previous tables show the difference between the current purchasing price (2021) and the price necessary to balance TCO and TCRO with respect to the DIESEL and CNG alternatives.

The data show how, in TCRO terms, the differential in favor of endothermic alternatives is currently very low, and corresponds to an extra investment cost of around 2 to 3% of the current price of the electric vehicle (while in the case of TCO the price decrease necessary to equalize the different options ranges between 11 and 12%).

A minimal decrease in the purchase price of electric vehicles would make them more convenient, as long as it is possible to exploit their potential in terms of B2G and monetize the residual value of the batteries for 2nd life uses.

The role of revenues, TCO and TCRO



GREEN elaborations, years 2021, 2025, 2030

Sources and methodological approach for the construction of scenarios 2030 and 2040 (IV) – Scenarios for projections

The three market scenarios (registrations and stocks):

These scenarios do not attempt to be precise forecasts, acknowledging the inherent uncertainties in a market context where both demand and supply are rapidly evolving.
They represent "what if scenarios" that are designed to achieve long-term climate policy objectives and operational efficiency of LPTO.

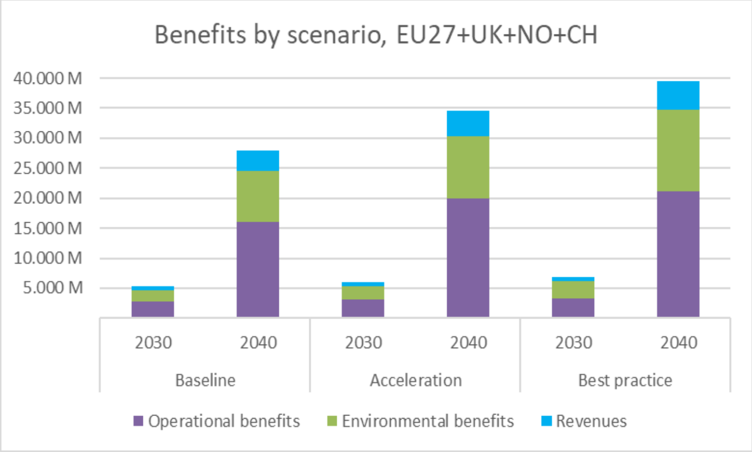
Projections from 2022 to 2030 and 2040 are elaborated for the different sets of 30 countries on the basis fo the following

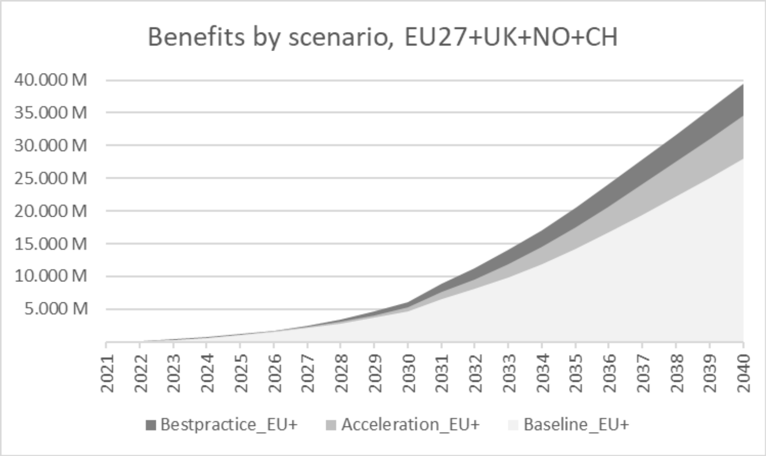
- **BASELINE**, assuming target for BEB from Clean Vehicle Directive –CVI (UE 1161/2019) are reached (differentiated among EU 27 countries, with an average of 22,5% BEB in 2022-2025 and 32,5% 2026-2030, between 2031 and 2035 different % among countries and after 2035 100%).

- **ACCELERATION**, anticipating by 2 years all CVI targets (65% starting from 2028 and 100% from 2033 instead of 2035)

- **BEST PRACTICE**, anticipating 100% BEB new registrations by 2028

Bus fleets electrification scenarios, operational+environmental+ revenues stream benefits EU 27+3 level – years 2022-2040 - 100% renewables case for electricity generation (cumulated results)





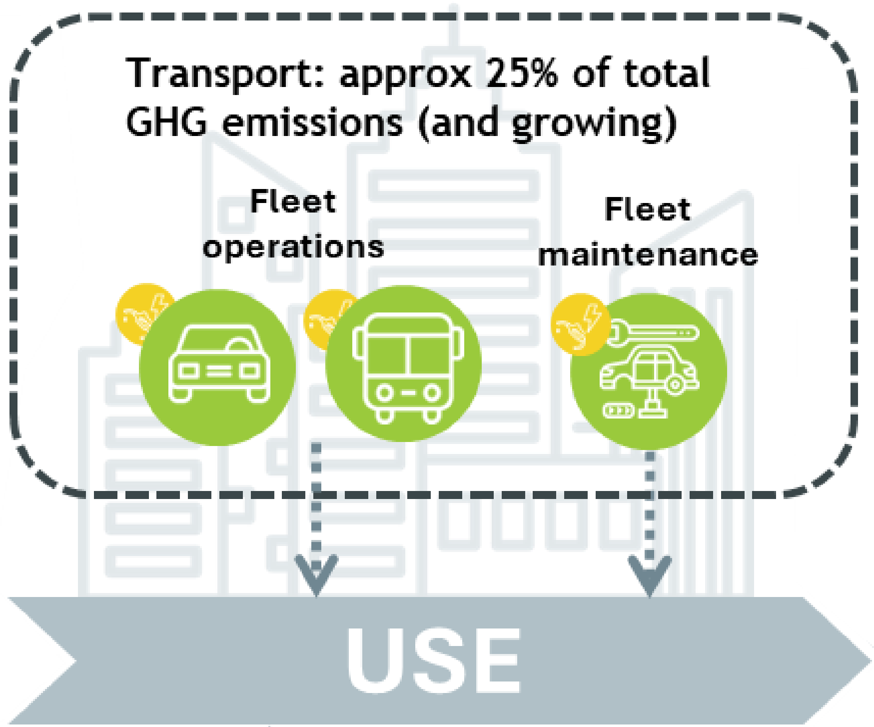
Source: GREEN elaboration

The contribution of swapping from diesel to electric buses to meet the efficiency goals of local public transport operators and to reduce the cost of environmental externalities for the society as a whole is relevant: up to 6,88 billion Euro in 2030 and 39,49 billion Euro in 2040 in Best practice scenario (anticipating 100% BEB new registrations by 2028).

In this scenario the project results underline that in 2040 the total benefits of each of the 180.133 e-bus part of the EU 27+3 stock market will be on average around 218.373 Euro.

Circular economy, public transport, rolling stock

Circular economy in the transport sector (I)



Circular economy in the transport sector (II)

The transport sector is carbon-intensive

Responsible for about a quarter of EU GHG emissions

The road transport sector is energy-intensive.

- The most significant energy consumer in the European Union –about 33% in 2019

Transport is resource-intensive

- Roughly 12% of steel produced worldwide
- Approx 70% of natural rubber production worldwide
- Approx 23% of aluminium worldwide

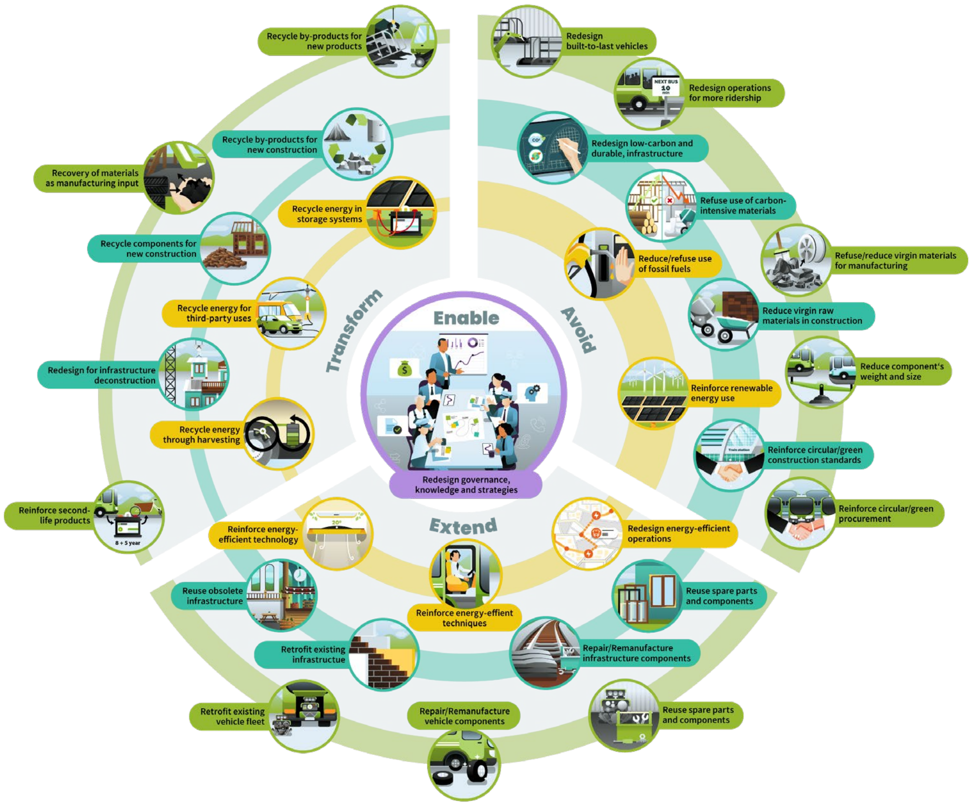
The increasing trend to e-mobility - especially private- will demand more energy, raw materials and critical raw materials.

- 10% demand energy increase (in the EU)
- 60% lithium, 30% cobalt, 10% nickel just for EV batteries worldwide
- Demand is expected to be 5 -10 higher compared to 2018

Circular economy in public transport

- **Public transport is already the most sustainable transport mode.** A modal shift to public transport can cut back tailpipe emissions by 50-70 %
- Further significant reductions can be achieved by **shifting to renewable energy and by addressing emissions along the whole value chain**
- As with electrification, **public transport leads by example and drives action** in other transport sectors
- Public transport has a **multiplier effect** in other economic sectors

The circularity compass



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Applied **7 R-principles** provide a catalogue of 30 actionable solutions to integrate and expand circularity in public transport along the entire value chain.

- Redesign
- Reduce/refuse
- Reuse
- Repair/remanufacture
- Retrofit
- Recycle
- Reinforce

https://circularity4publictransport.eu/circularity-compass/

The circularity compass: a vision

From a **take-use-throw** to an **avoid-extend-transform-enable** model

AVOID → EXTEND → TRANSFORM

Fleets

Self-propelled machines are designed to carry passengers between different locations (buses, trolleybuses, trams, and trains). Circular vehicles are equipped with energy-efficient technologies and alternative propulsion systems and are designed for durability, repairability, and recyclability

Infrastructure

Underlying system of built and fixed structures, installations and facilities that support public transport operational activities.
Circular infrastructures maximise resource efficiency, prioritise using, reusing, and recovering low-carbon and high-quality materials, and are designed for durability and disassembly.

Energy

Fuels employed to generate the power, heat, or electricity essential for conducting public transportation activities and operations.
Circular public transport systems are powered by renewable energy, and their use is optimized throughout the lifecycle of processes and operations.

Governance

System of policies, structures, processes, institutions, and mechanisms that guide decision-making, promote stakeholder management and facilitate the transition to a circular economic model.

The strategies

Closing circularity gaps:

→ by better use of waste energy and RES

→ to add, recapture value and optimise delivery of PT infrastructure

→ **to recapture value and optimise delivery of vehicles and rolling stock**

Building a strategy to recapture value and optimise delivery of vehicles and rolling stock

Focus on:

- Stimulating improvements along the supply chain
- Tendering procedures
- Information and data
- Safety and circularity
- Creating case history and proofs of concept for innovations

Methodological steps

SIET

- Workshops with project partners (co-creation)
- In depth interviews with PTOs (3)
- Questionnaire with suppliers (14)
- Workshops with suppliers (collection of feedbacks)
- Validation by Advisory Board (validation)

Status quo (questionnaires + workshops)

Approach	*Status*
AVOID	• Circularity potential of some parts of the supply chain is limited • Lack of awareness on the demand side (why circular?) • Limited use of LCA and EcoDesign
EXTEND	• Research is needed to improve recycled material performance • Define design for disassembling methodologies to facilitate reconversion in the future • Need to raise awareness of the supply chain
TRANSFORM	• Batteries: define approaches for traceability (battery passport) • Product design and components to facilitate recycling

Swot analysis (workshops)

SIET

STRENGTHS:	WEAKNESSES:
• Link between electrification, resource efficiency and circularity • Synergies between safety and circularity • Long term benefits (environmental, economic)	• Difficulties in adopting a systemic approach • Financial constraints • Power of suppliers • Transparency of information
OPPORTUNITIES:	**THREATS:**
• E-Buses are an opportunity to put the customer at the center of the process • Create conditions to engage contractors in tendering procedures • Foster EU rules on circularity	• Technology lock-ins • Dependence on external supply (e.g. maintenance) • Availability of resources for complex projects

Vision and objectives for a strategy

VISION: PTOs at the centre of the life cycle, from manufacturing to circularity

Objectives:

- A new generation of tendering procedures and contracts
- Increase transparency on data
- Coupling Safety and Circularity
- Create cases for innovative approaches to circularity (2nd life, bus2grid, renewable energy communities)

Portfolio of possible measures

SIET

- Develop tendering procedures and contracts (for rolling stock, equipment, components, services e.g. maintenance) fostering the adoption of circularity, through LCA EcoDesign (and other) approaches and standards

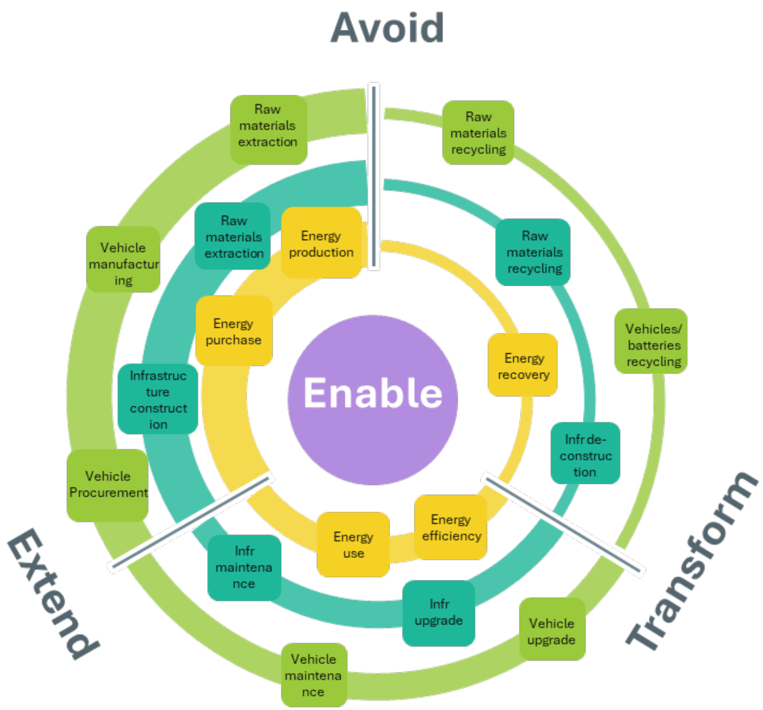
- Design an assessment and labelling model for suppliers along the supply chain

- Elaborate KPIs and requirements for new platforms/monitoring tools for diagnosis of batteries and other components (e.g. Digital twins)

- Analise the impact of Safety measures enhancing Circularity (e.g. Monitoring systems for batteries, fire hazard controls, etc.)

- Develop tests and feasibility studies for innovative approaches to circularity (2nd life, bus2grid, renewable energy communities)

Grazie per l’attenzione!



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CE4CE in a nutshell

SIET

Greening public transport

Public transport helps to lower emissions but it is still resource- and waste-intensive in itself. The CE4CE project reduces the ecological footprint of public transport through a higher circularity. The partners identify circularity gaps and develop innovative circular economy models for planners and operators. They provide guidance on how to incorporate circular economy principles into procurement processes for services and infrastructure and design more circular products and business models.

interreg-central.eu/projects/ce4ce

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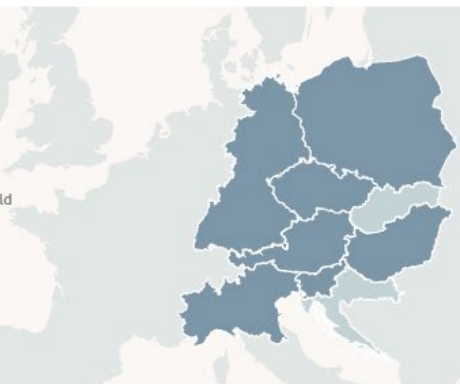
CE4CE

COUNTRIES & REGIONS

AUSTRIA	Salzburg | Wien
CZECHIA	Praha
GERMANY	Sachsen
HUNGARY	Budapest | Dél-Alföld
ITALY	Lombardia
POLAND	Pomorskie
SLOVENIA	Vzhodna Slovenija



2,74 million € Project budget

80% ERDF co-financing

12 Partners

6 Pilots

04.2023 Start date

03.2026 End date

Information based on application form | December 2022