Life Cycle Assessment (LCA) of
Nickel Metal Hydride Batteries for HEV Application

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Funding Partners of the LCA

- **RECHARGE aisbl**
- **European Nickel Industry Association (ENIA)**
- **Toyota Europe**
- **Umicore**

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LCA of Ni-MH Batteries for HEV

OVERVIEW System Boundaries

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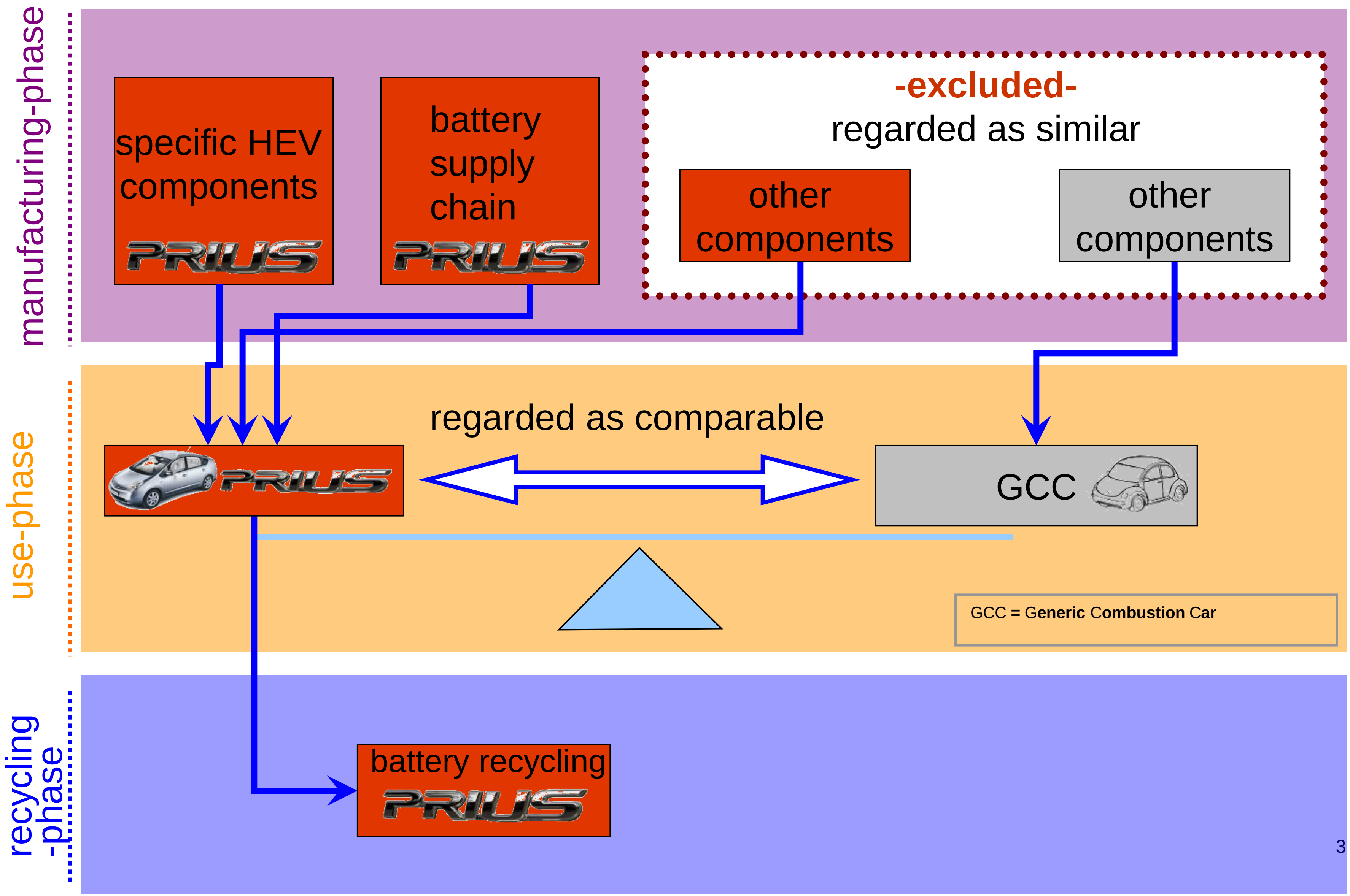

Goal of the LCA study

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- Investigation of main parameters for the environmental performance of the Toyota Prius II Ni-MH-battery
- Identification of main potentials for an optimization of the HEV battery production chain
- Impact of additional components such as electric motor for an LCA on complete HEV-equipment,
- Impact of HEV battery recycling (Nickel, Cobalt, Copper, Steel)
- Impact assessment of the HEV battery versus fuel savings over the entire life cycle

Main Data Sources

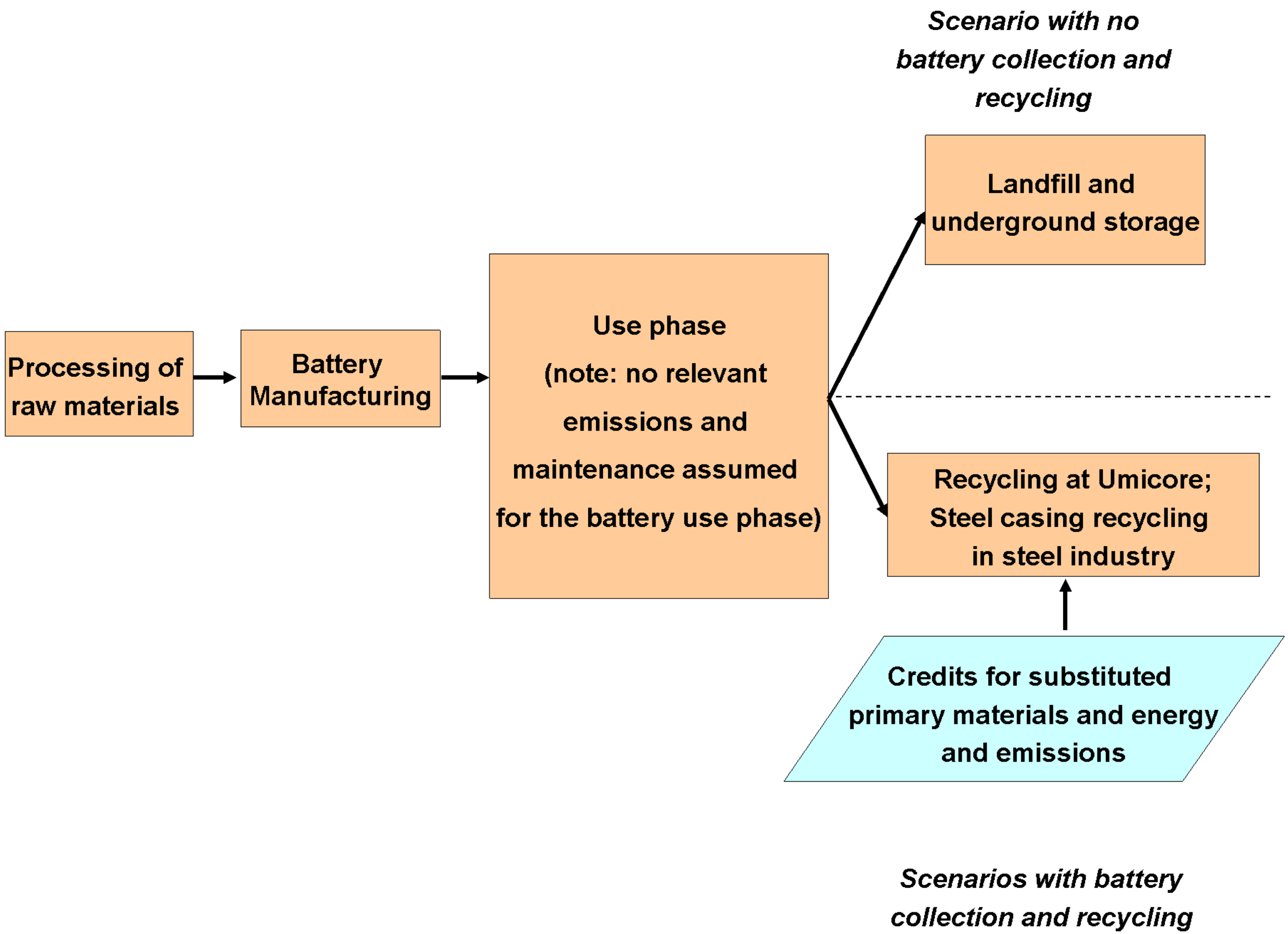
- First hand data of the funding partners regarding battery manufacturing, battery recycling and use phase,
- Ecoinvent 2.01 data-base,
- GEMIS 4.42 data base,
- Special literature regarding Ni-foam, rare earths etc.

Limitations of the LCA study

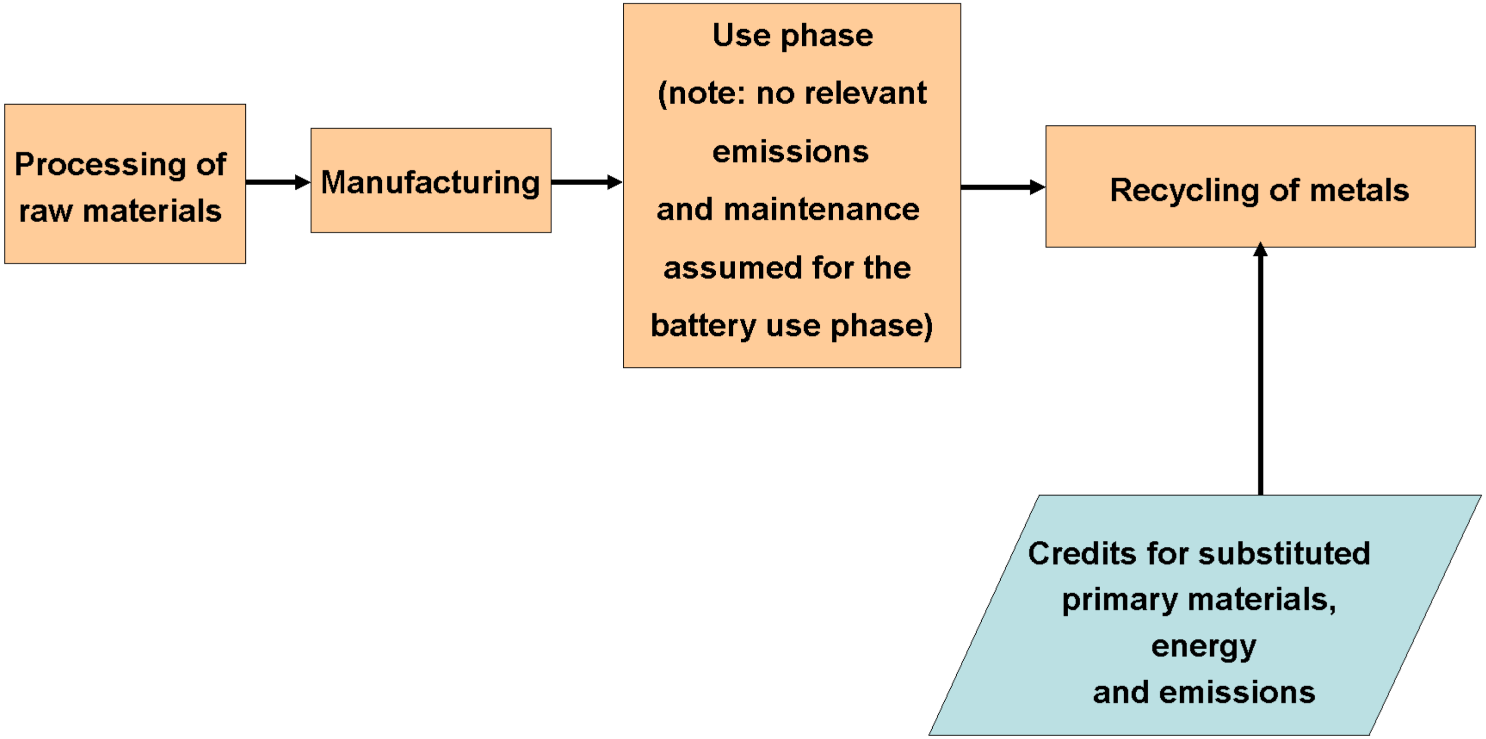
- Effects on biodiversity can not be displayed
- Due to data problems the human toxicity potential can not be assessed
- LCA according to ISO 14040/44: for the Ni-MH battery (including recycling)
- Orientating LCA for the additional components and the impacts of the HEV use phase

Nevertheless, the overall results are quite robust!

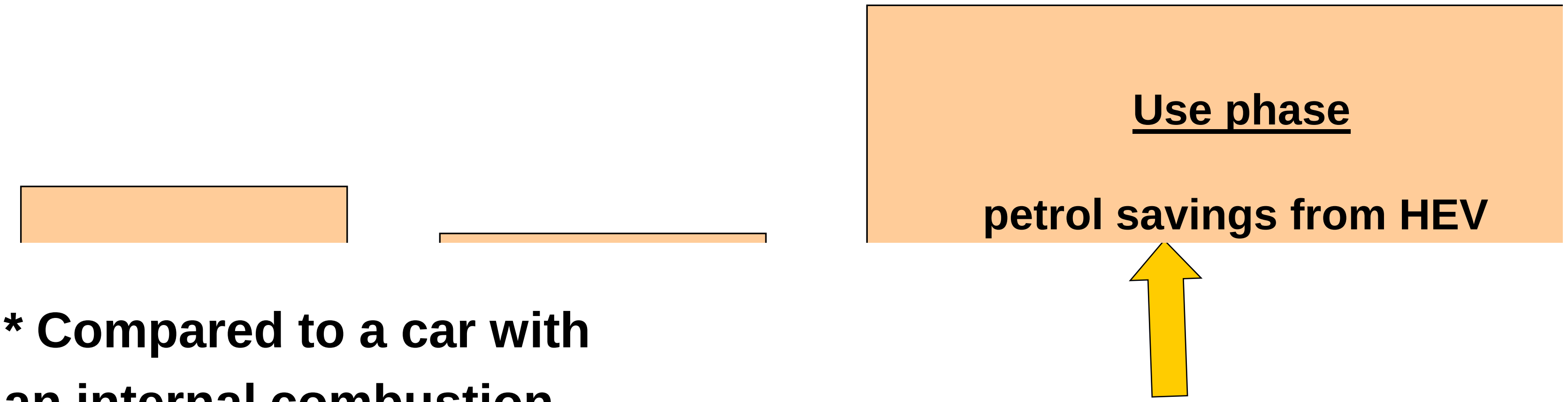
Battery Production and Disposal



Additional Components



Use Phase



*** Compared to a car with an internal combustion engine (ICE): 45 % or 1.2 liter/100 km due to HEV technology**

150.000 km

petrol saving of a PRIUS II: 2.5 liter/100 km*

LCA-Methodology

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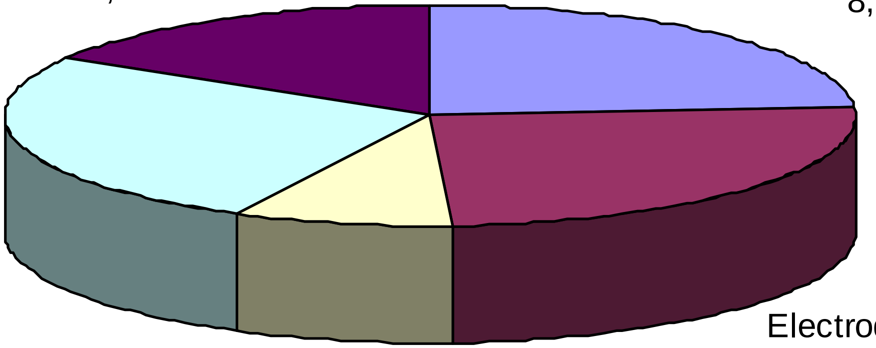
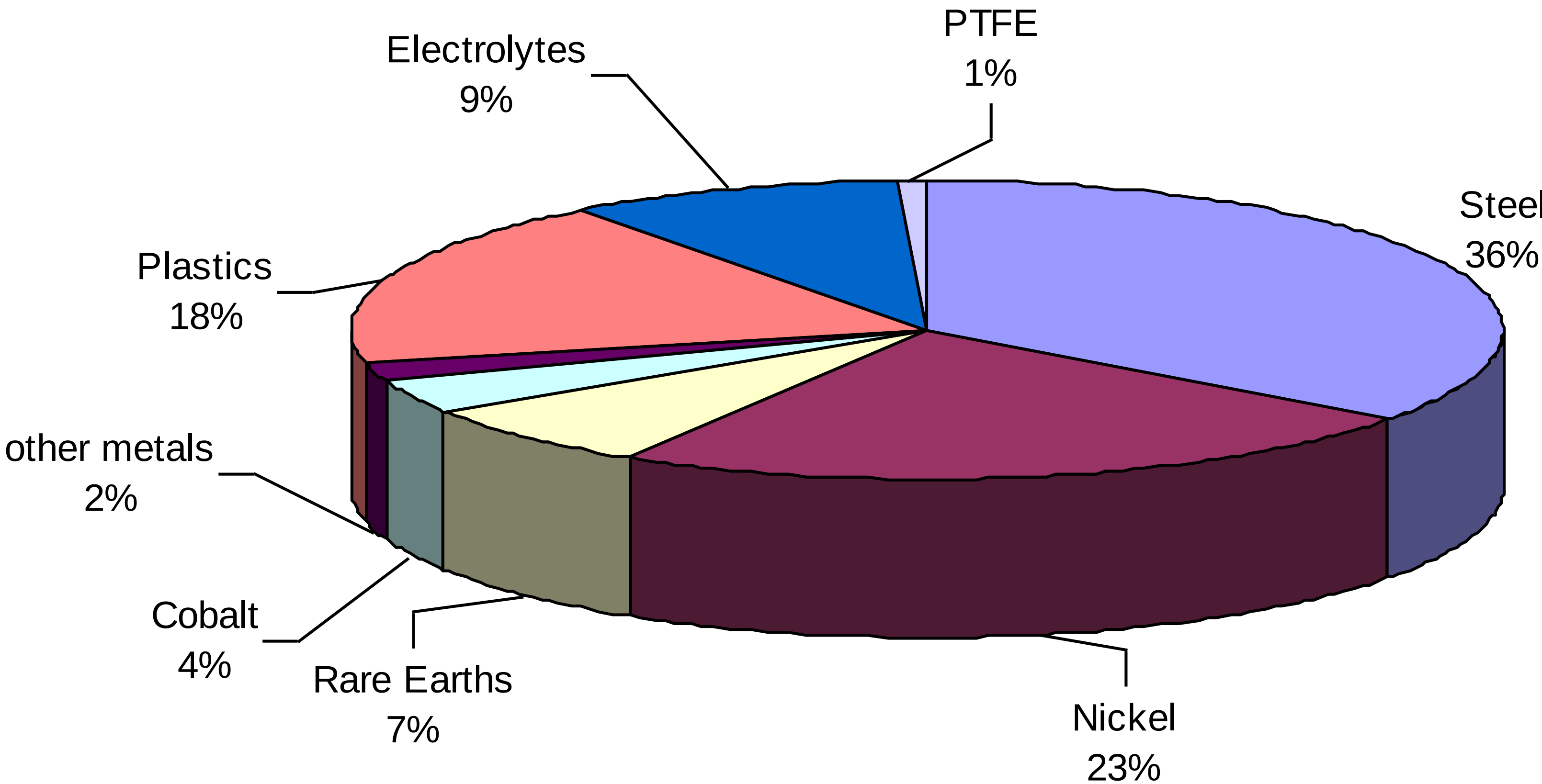
- **According to ISO 14040/44**
- **Environmental impacts:**
  - Global Warming Potential
  - Acidification
  - Eutrophication
  - Photooxidants
  - Ozone layer depletion
  - Non renewable energy carriers
  - Depletion of Ni and Co resources
- **Characterisation factors according to CML / IPCC**
- **Critical Review by Mr. Hischier (EMPA)**

Mass Balance of HEV Battery 1/2



Total battery: 35 kg

Mass Balance of HEV Battery 2/2



Mass Balance of Additional Components

	netto weight (kg)	Estimated recycling quotas (%)
aluminium	9,6	80
iron	27	95
steel, high alloyed	1,7	80
copper	20,7	80
plastics	7,6	
carbon	1,9	
silica	9,5	
not specified	8,4	
total	86,4	

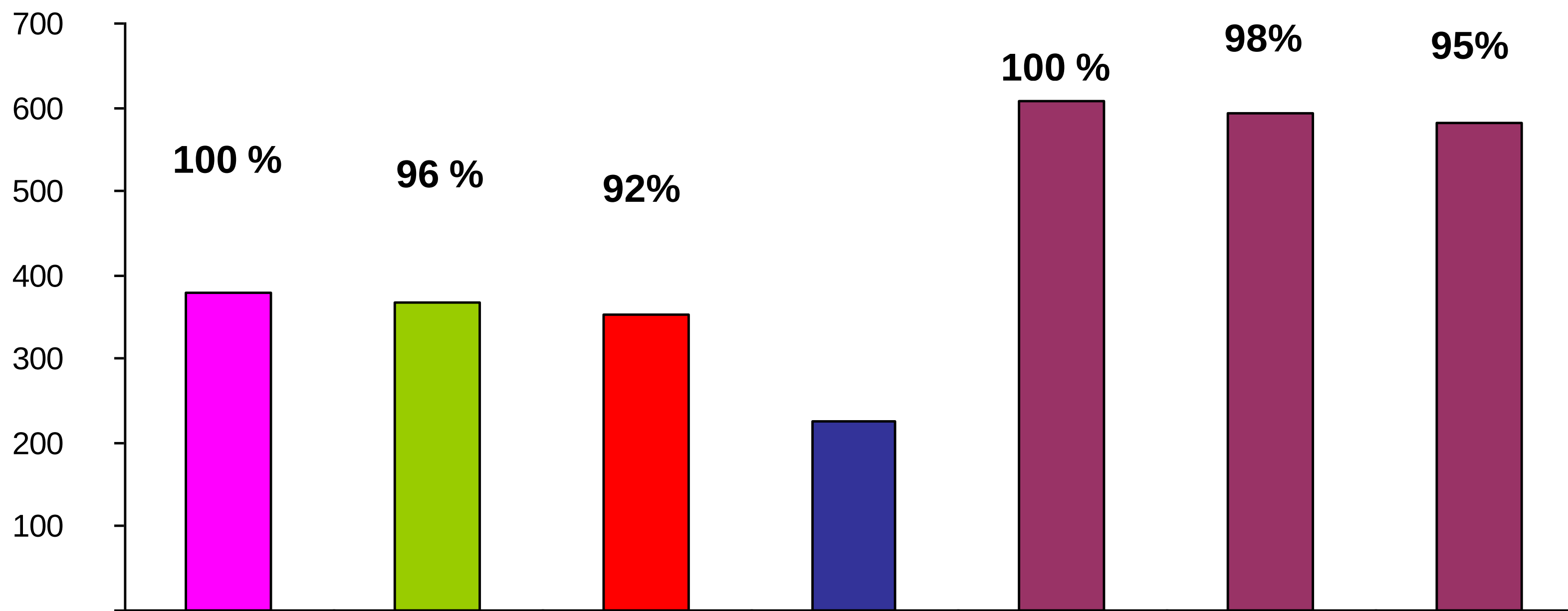
Sources:

Netto weight: study by JRC ipts on hybrids for road transport (Christidis et al. 2005)

Recycling quotas: estimation by Oeko-institute for European average

Results (I)

GWP of battery (different recycling rates) and additional components



	battery - no collection	battery - 50 % collection	battery - maximum collection	additional components	Total - no battery collection	Total - 50 % battery collection	Total - max. battery collection
kg CO2-eq	379	366	353	227	606	593	580

- **Moderate reductions of the GWP in the case of battery collection and recycling – further GWP-reductions are possible via up-scale of the recycling process and re-use of heat!**

Results (II)

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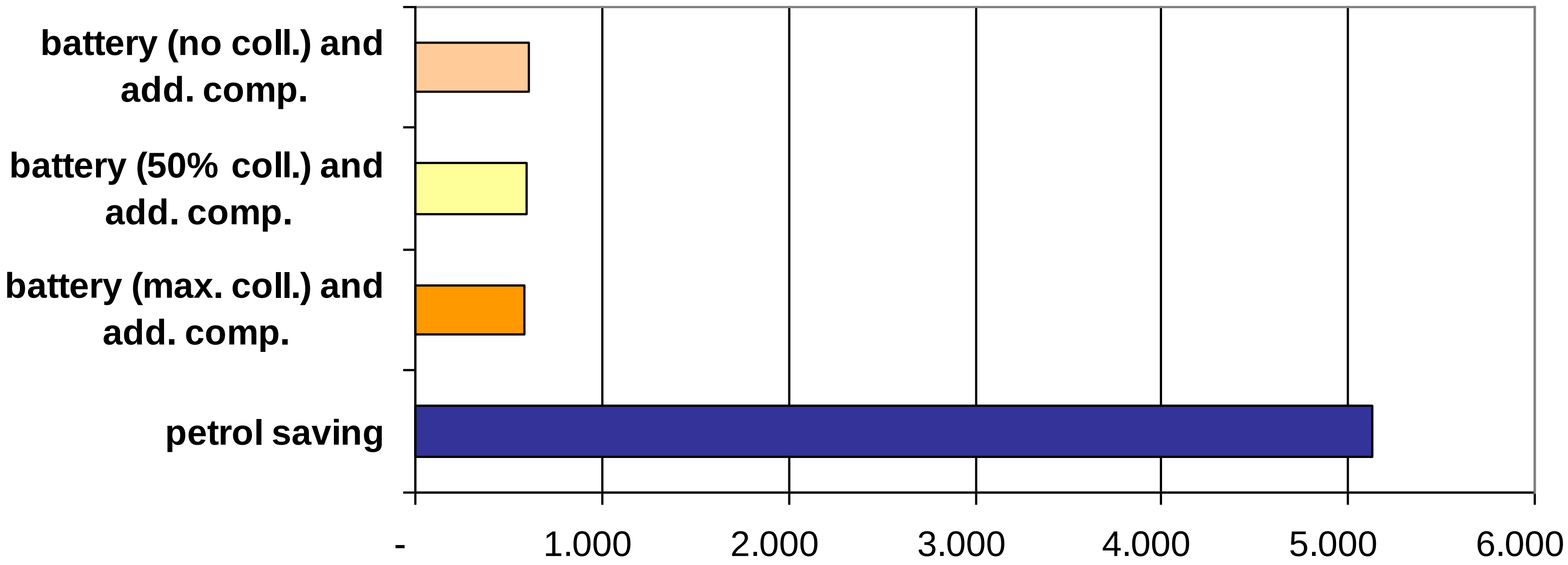
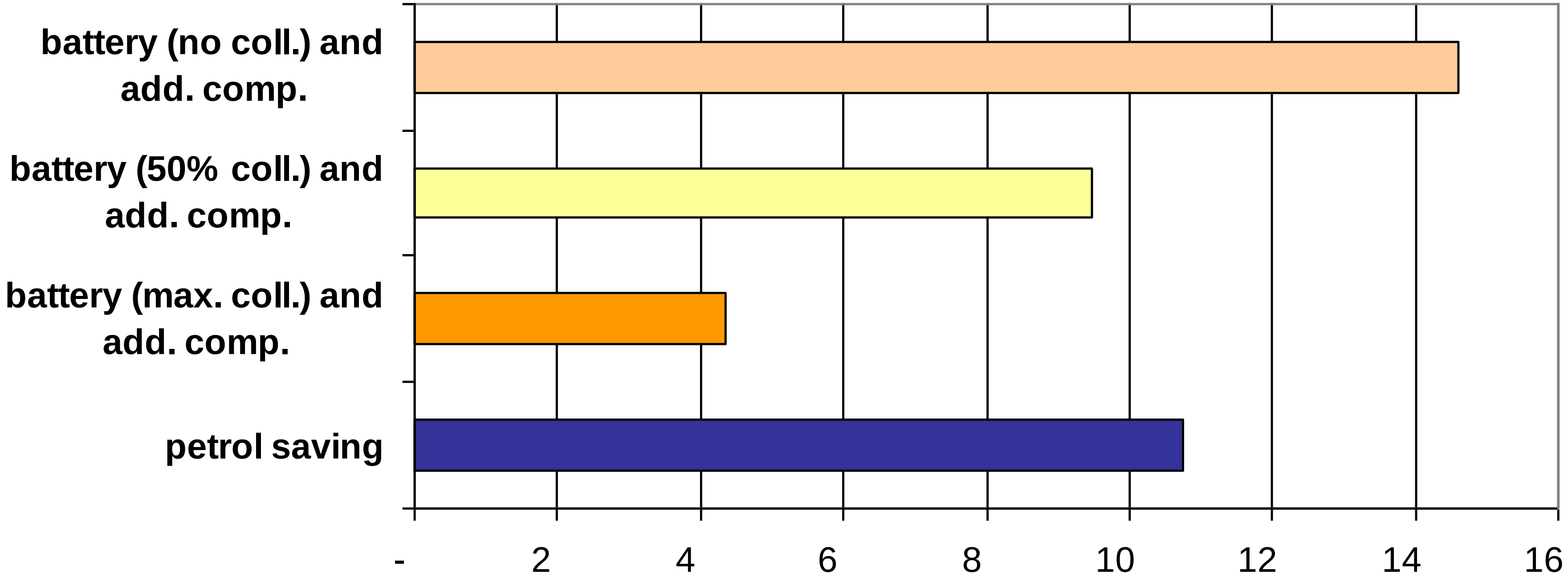
GWP of fuel saving versus battery life cycle at different battery recycling rates (kg $CO2_{-eq}$)



- About factor 9 regarding petrol saving!
- Results for non-renewable energy carriers are quite similar!

Results (III)

AP of fuel saving versus battery life cycle at different battery recycling rates (kg $SO_{2\text{-}eq}$)



- **Conclusions: At least 50 % of the batteries should be recycled with high Nickel and Cobalt recovery rates!**
- **Results for eutrophication are quite similar!**

The Benefit of Battery Recycling

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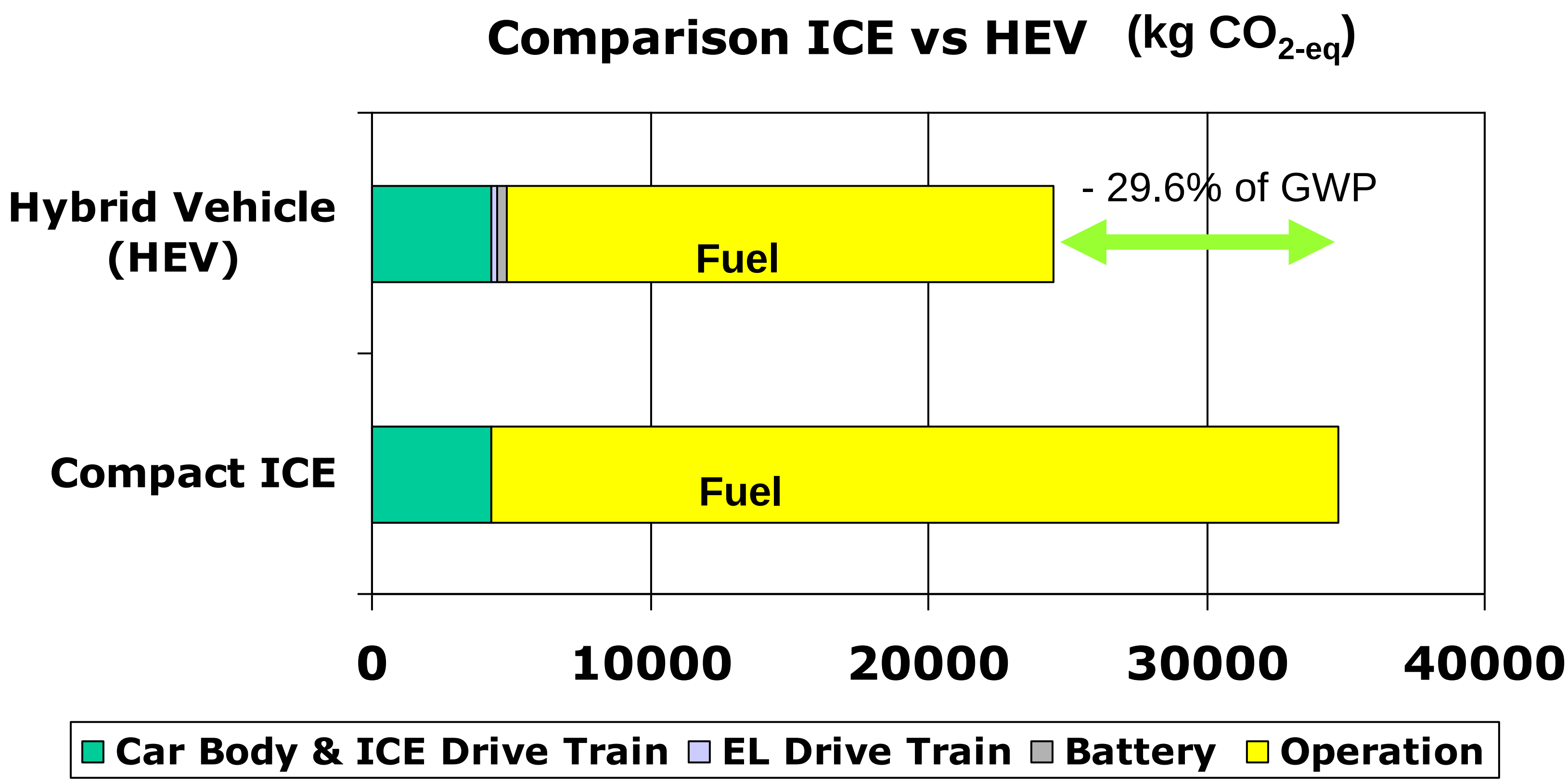
- Huge reduction of the acidification and eutrophication potential!

- Resource conservation regarding Nickel, Cobalt, Copper, Iron ores!

- Reduction of GWP and demand on non-renewable energy carriers!

Results (IV) GWP ICE vs HEV



HEV Prius II allows nearly a 30% reduction for GWP compared to ICE Corolla – The battery and E-drive contributes 45% (4.550 kg $CO_{2\text{-eq}}$) to the fuel economy

Data car body: VW Golf; Fuel data ICE: Corolla; Fuel data HEV: Prius II

Conclusions I

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- Fuels savings by Ni-MH battery for HEV applications exceed manifold the load from the battery manufacturing chain for the GWP and the non-renewable energy carriers! (Around factor 9 for GWP)
- GWP reduction potential for a HEV technology as realized in the Prius II: 10–15% of entire life cycle of standard car with combustion engine and 150.000 km (reduction of 4 – 5 t $CO_{2\text{-eq}}$).
- Primary nickel supply chain is responsible for 90% of the acidification and eutrophication potential respectively within the battery supply chain (without battery recycling and without secondary nickel input)

Conclusions II

- A share of 50% or more recycling regarding the HEV battery reduces the acidification and eutrophication potential remarkably. Maximal collection and recycling rates of 99 % reduce EP and AP by 80 – 95%.
- A maximal collection and recycling of the HEV batteries also reduces the depletion of Ni and Co resources by more than 90%.
- Recyling processes with high energy efficiency or re-use of heat production should be favourized as they will have an additional positive impact on GWP-reduction.
- The additional components such as the electric motor have a relevant contribution to the HEV-equipment. An LCA on HEV must include these components and may not only consider the battery.

The industry in Europe has to realize an appropriate collection and recycling system for HEV and EV batteries as an important contribution to resource conservation!

Thank you for your attention!