Willkommen
Welcome
Bienvenue

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Life Cycle Assessment of conventional and electric bicycles

Eurobike 2011

Friedrichshafen, 2. September 2011

Andrea Del Duce

Outline

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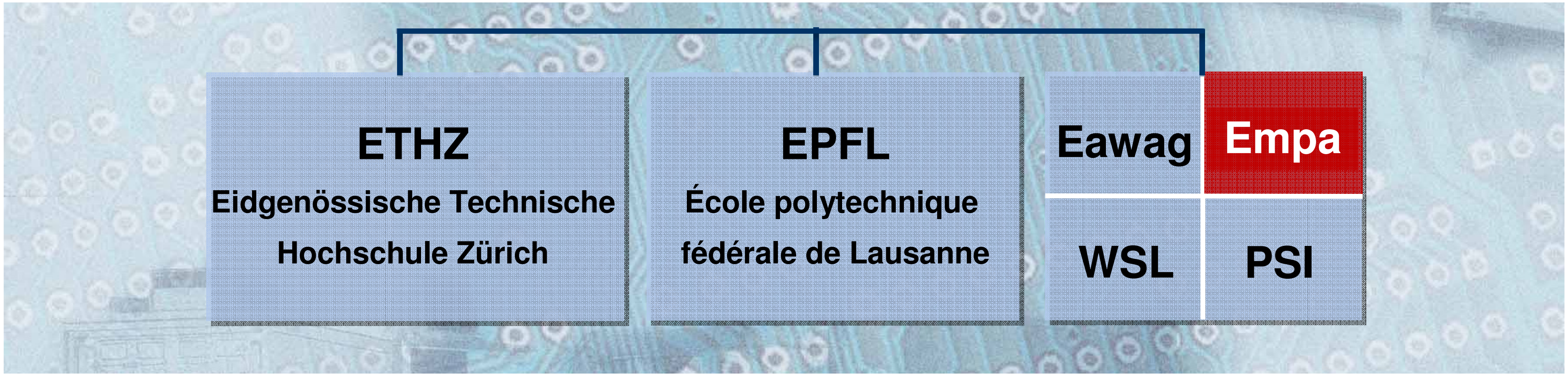
- The Empa and LCAM
- Life Cycle Assessment
- Introduction to the context of the study
- The Li-Ion battery and the electric drivetrain
- Life Cycle Inventory of two wheelers
- Life Cycle Impact Assessment results
- Conclusions

The Empa

- Empa - Swiss Federal Laboratories for Material Science and Technology: Dübendorf (Zürich), St. Gallen and Thun
- Research Institution within ETH Domain:



- Vision: Materials and Technology for a Sustainable Future
  - Materials for Energy Technologies
  - Health and Performance
  - Natural Resources and Pollutants
  - Nanostructured Materials
  - Sustainable Built Environment
- Bridging between Research and Application

LCAM – Life Cycle Assessment and Modelling Group

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- Investigate environmental impacts and sustainability of products or services through Life Cycle Assessment.

- Support informed decision making.

- LCAM activities:
  - LCA of key topics
  - Refining, expanding and complementing LCA methodology.
- Areas of interest:
  - Biofuels and bioenergy
  - Buildings, construction components and materials
  - Emerging technologies
  - Electric mobility

LCAM e-Mobility

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- In depth study of the environmental impacts caused by Lithium-Ion batteries.
- Comparison of environmental impacts caused by a virtual model of an electric Golf VW and by various ICE versions: petrol, diesel, biofuels, hybrid. (Axpo study)
- Since 2-wheelers represent a practical alternative to cars, the environmental impacts of bikes, e-bikes, e-scooters and scooters have also been analysed.
- THELMA project: aims at understanding the sustainability implications of widespread electric vehicle use in Switzerland.

THELMA

Life Cycle Assessment

Electricity production

Car disposal

Problem-shifting

Materials production

Mining

Life Cycle Assessment 2

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Resources:
Metals,
Plastics,
Electricity,
Oil,
……

Production

Use

End of life

Emissions:
CO_2,
NO_x,
SO_2,
radioactive waste,
……

Impact factors: Global warming, Resource consumption, Toxicity, etc.

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Electric Bicycle

ICE Scooter

Bicycle

LCA

eScooter

Golf VI

Elektro-Golf VI

Goal and scope of the LCA

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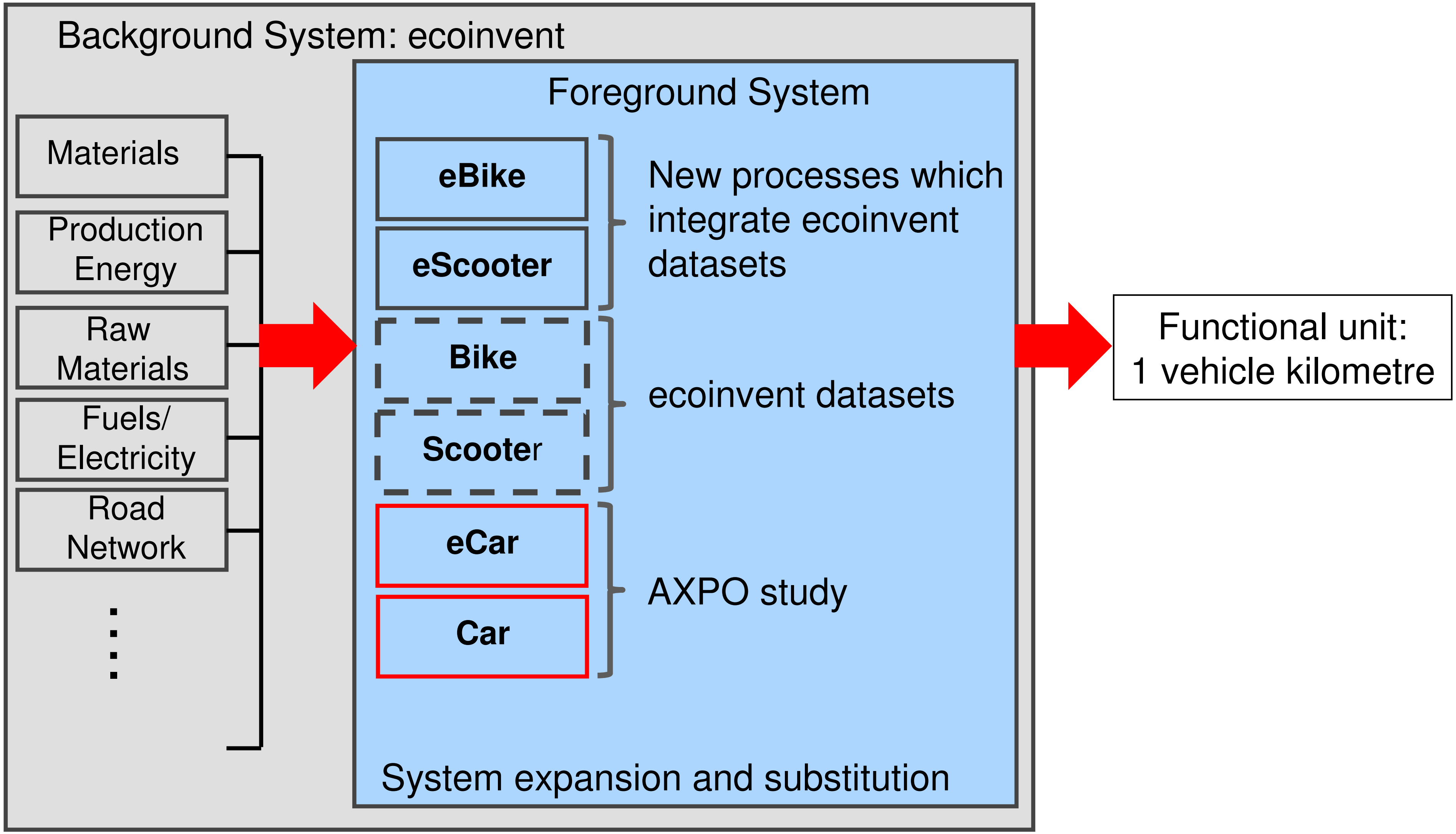
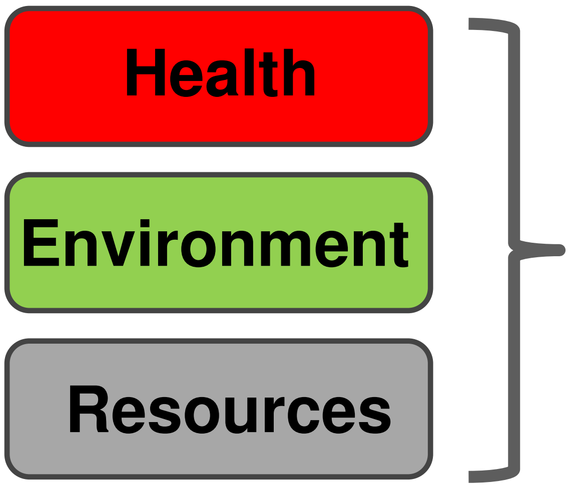
- Compare current electric and conventional two wheel vehicles as well as analysing these results in the context of conventional and electric cars.
- Focus mainly set on Swiss situation (e.g. Swiss electricity mix)
- Contribute to the discussion on individual mobility and on the potentials (or disadvantages) brought by electric two-wheelers.

Life Cycle Model



Impact assessment methods considered

- Global warming potential IPPC 2007
- Toxic emissions: CML01 HTP
- Smog formation: CML01 POCP
- Land use: CML01 LUC
- Eutrophication: CML01 EP
- Non renewable energy demand: CED fossil, nuclear
- Exergy demand: CExD metals, minerals
- Ecoindicator 99 (H/A)



Aggregates impacts into a single parameter: Ecoindicator Points

The electric drivetrain

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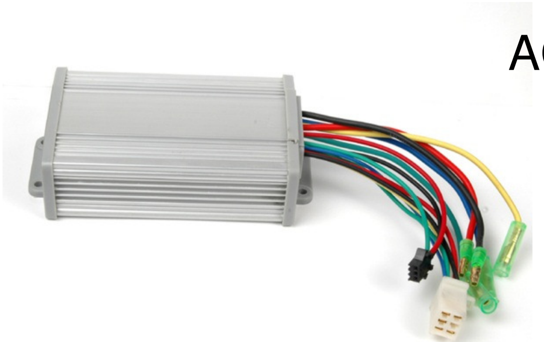
DC energy



AC energy

Li-Ion battery

Controller

Hub motor

Charger

Lithium-Ion Battery 1

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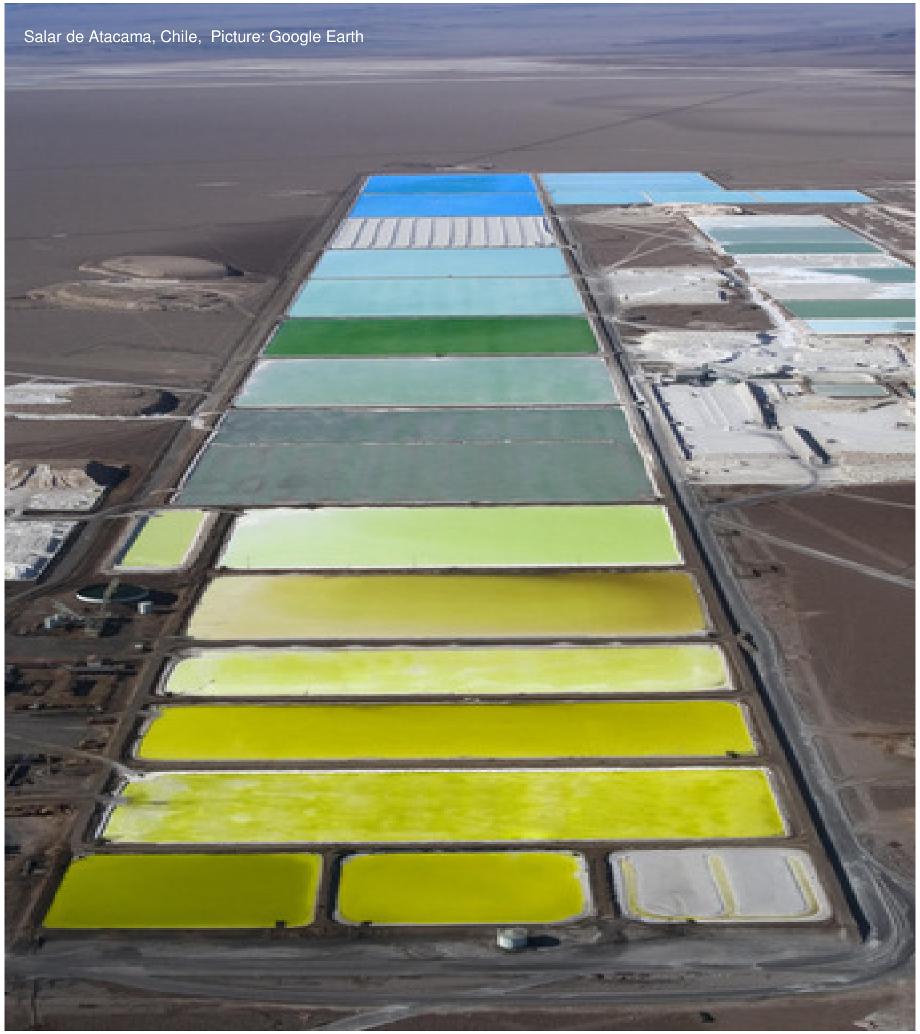


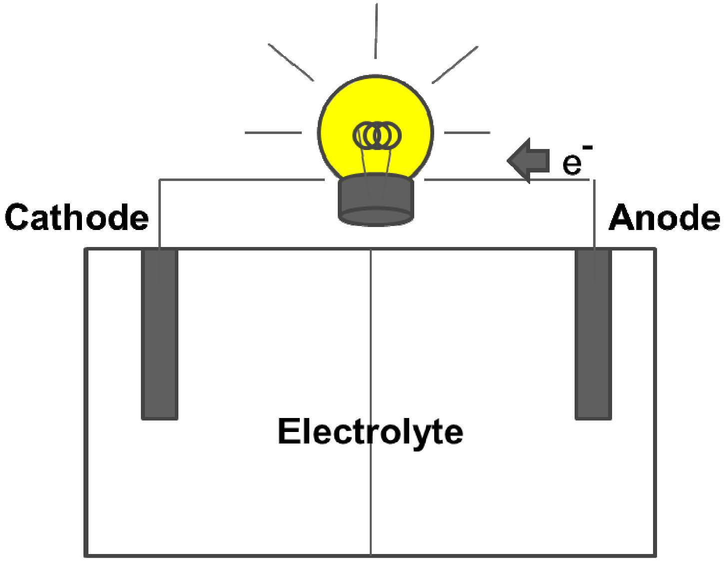
Lithium properties

- Lightest metal
- Highest electrochemical potential
- Not toxic (used as medicine)
- Not scarce (e.g. more abundant than Cu, 0.17 ppm in sea water)
- Highly reactive in metallic form (burns!)

Production

- Mainly won from salt lakes in the Andes (Chile, Bolivia) or in China (Tibet)
- Mainly solar energy used for production
- Refined to Lithium carbonate (Li_2CO_3) near the saline

Lithium Ion Battery 2

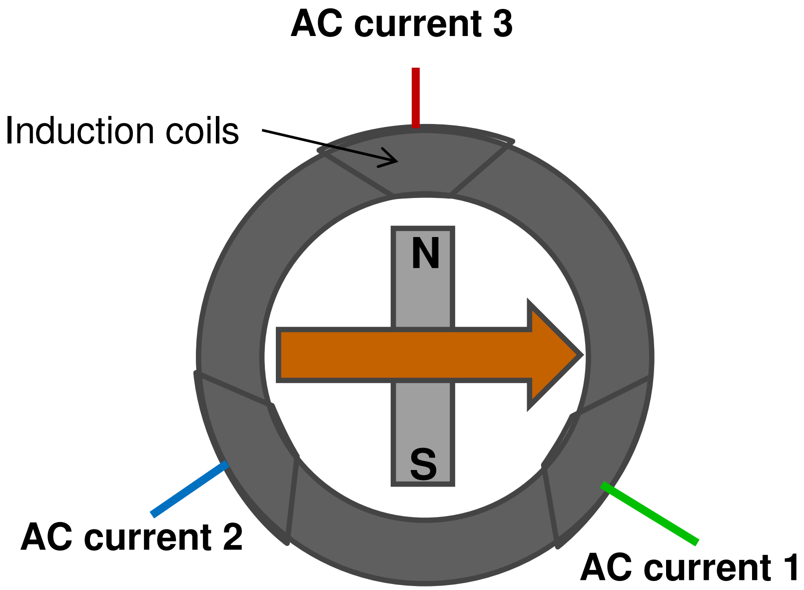


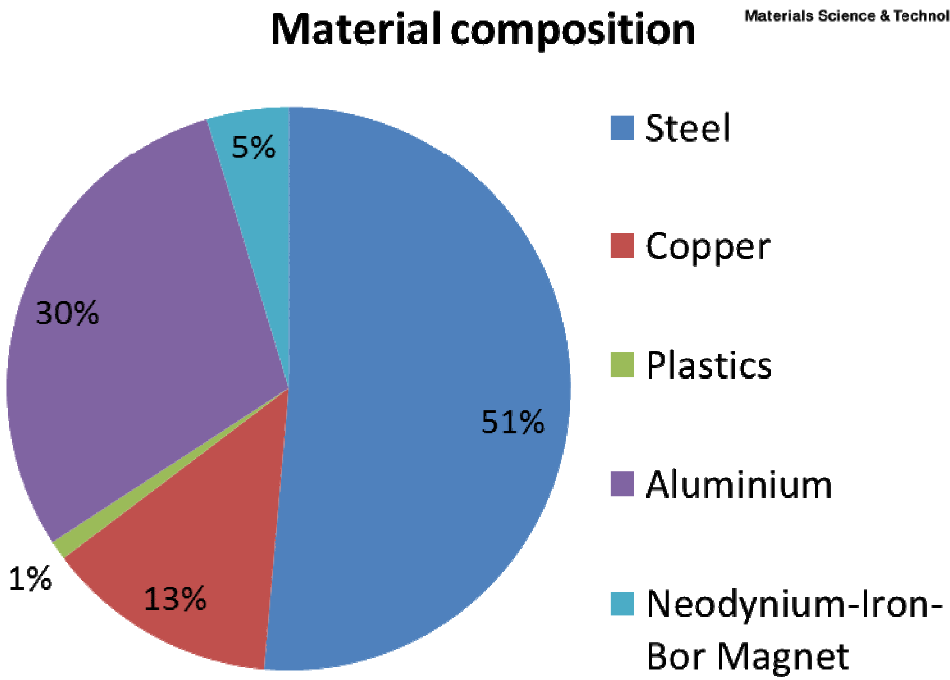
Cathode: $LiMn_2O_4$
(obtained from Li_2CO_3 and Mn_2O_3)
applied over Aluminium foil

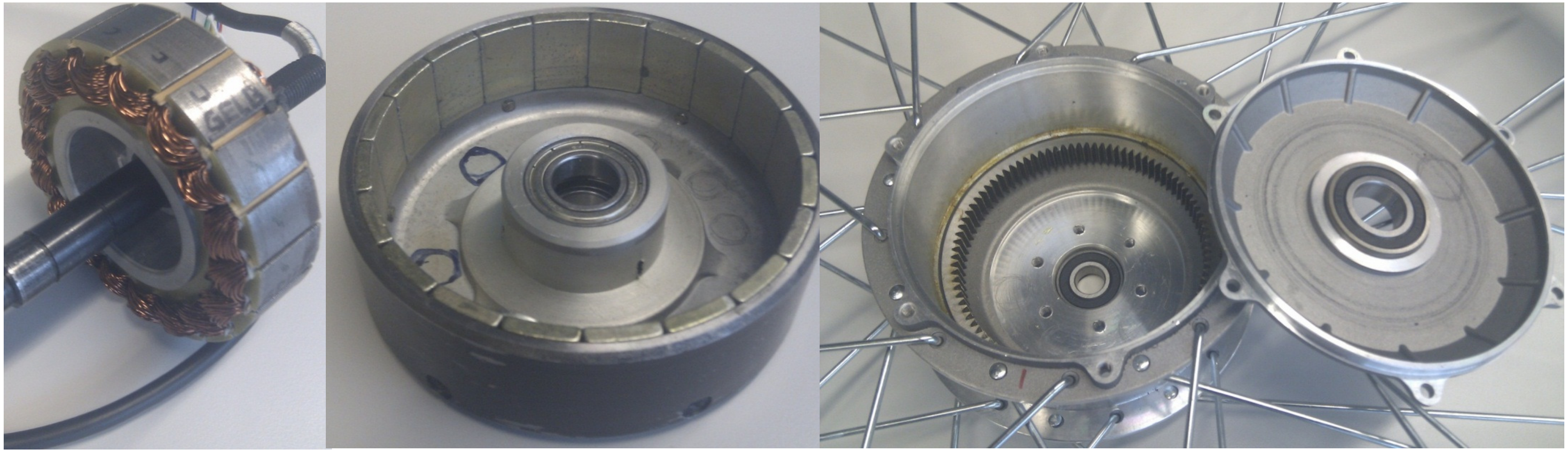
Anode: Graphite
applied over Copper foil

- Only ~1% of a Li-Ion cell is Li
- ~40% of a cell is Al (~23%) and Cu (~13%)
- ~40% is the active electrode material (cathode LiMn2O4 ~24%, anode graphite ~16%)
- ~20% is the electrolyte (lithium salt)

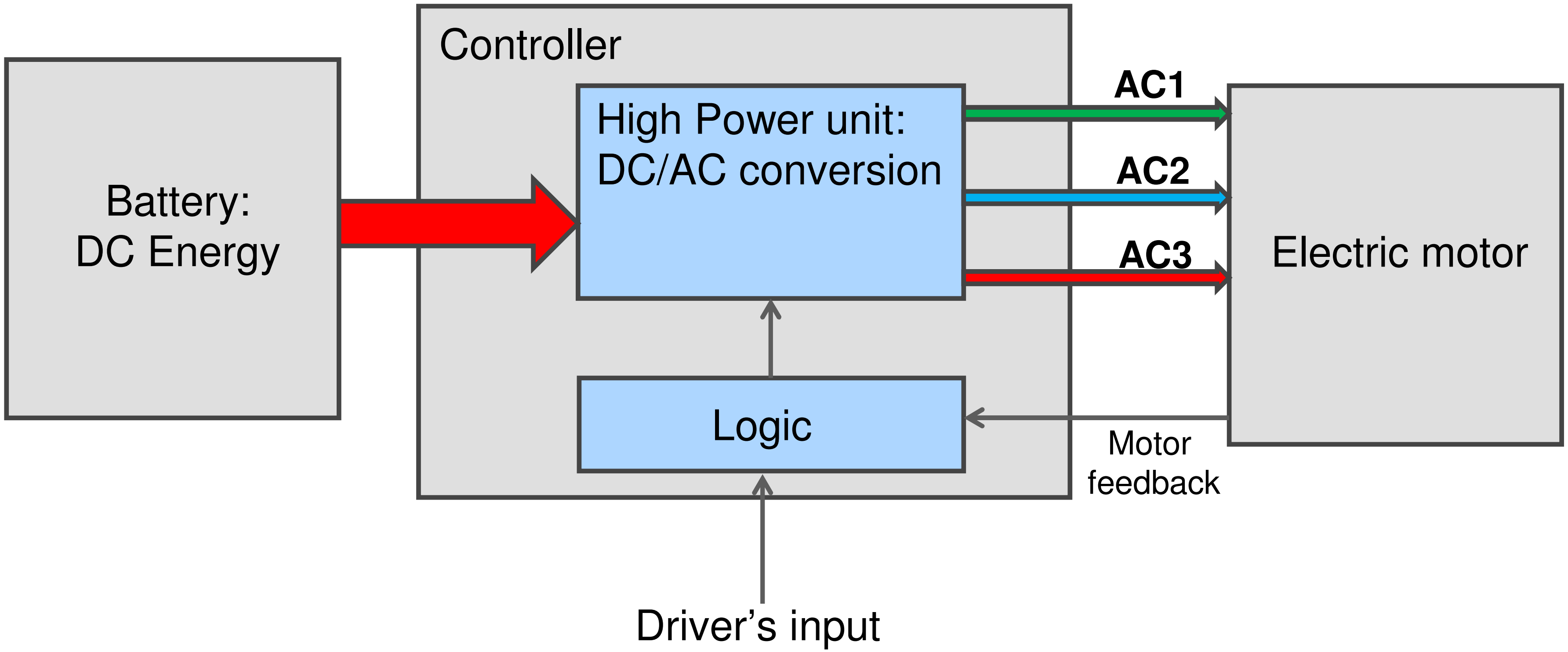
The electric motor



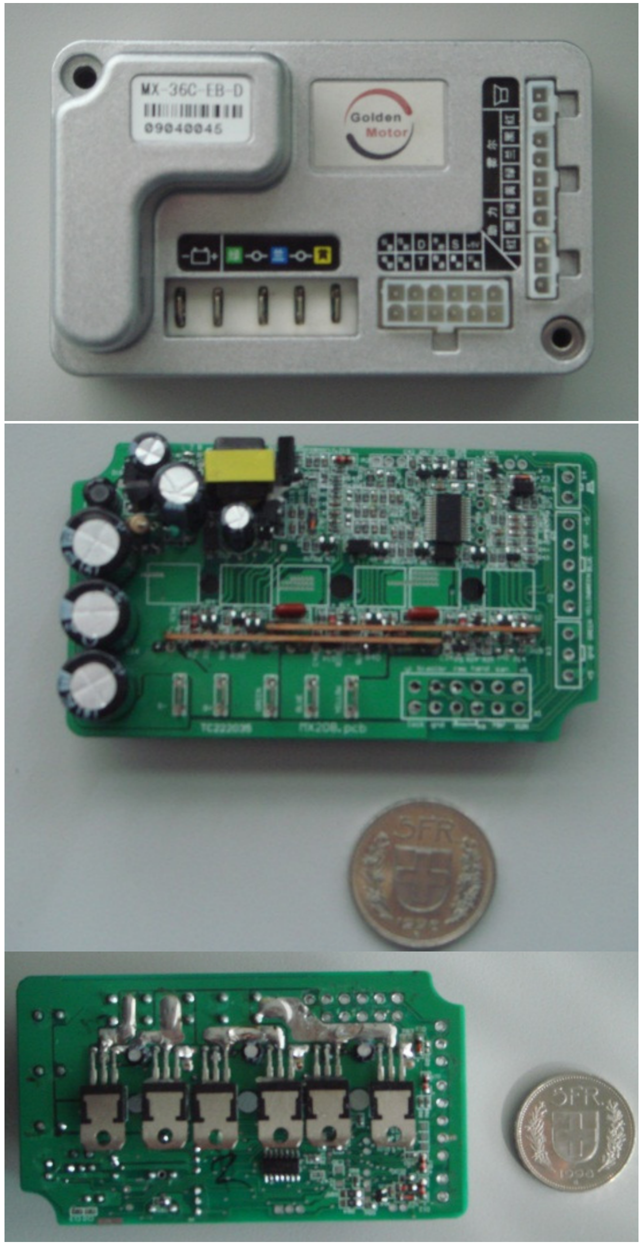




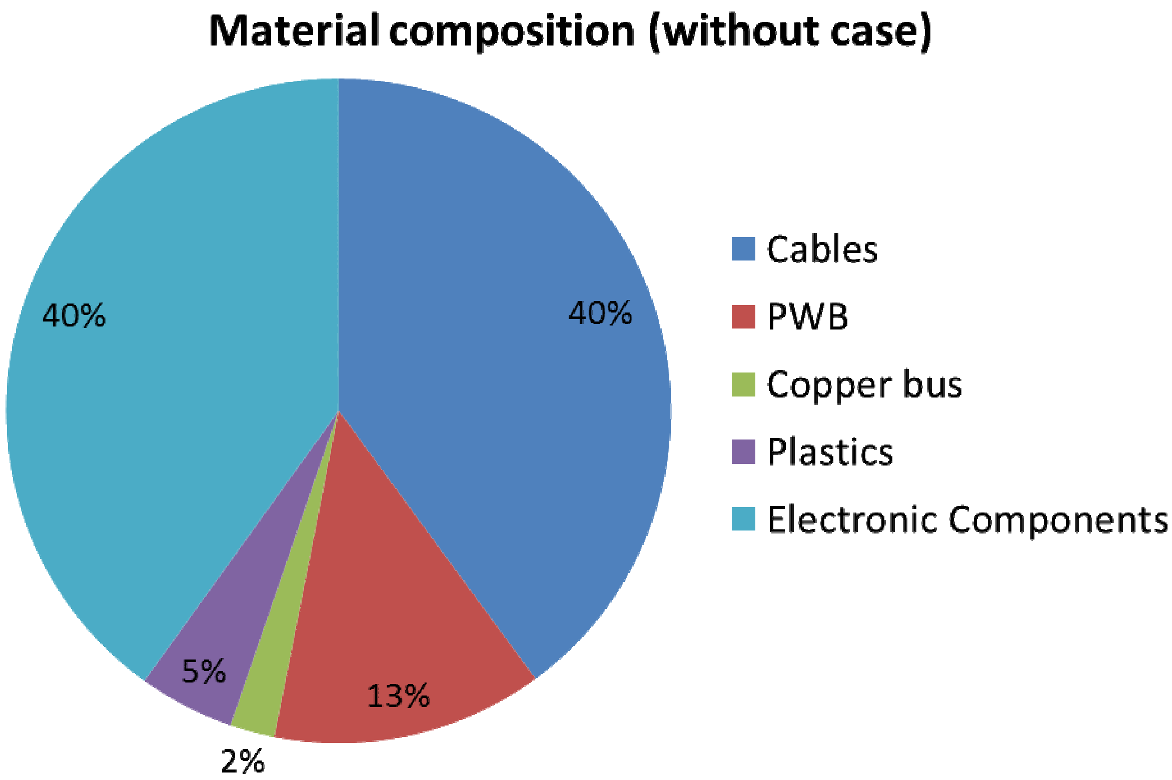
The controller



The controller 2



Overall: ~63% is Aluminium from the case



Bikes and eBikes

Standard ecoinvent bike

Bike:	
Weight	17kg
Life expectancy	15000km
Maintenance	50% of plastic
	5% of steel
	tyres every 4000km

eBike	
Frame	Identical to bike
Controller	0.4kg
Charger	0.5 kg
0.25 kW electric motor	2.7kg
Li-Ion battery	2.6kg
Total weight	~23kg
Life expectancy	15000km
Electricity consumption	0.01kWh/km
Maintenance	50% of plastic
	5% of steel
	tyres every 4000km
	2.75 Li-Ion battery

eScooter and Scooter

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eScooter	
Weight	~140kg
Li-Ion battery	32kg
Controller	1.3kg
2.7kW eMotor	5.8kg
Charger	~3kg
Consumption	0.057kWh/km
Life expectancy	50000km
Maintenance	23% of plastic
	10% of steel
	10% aluminium
	tyres every 5000km
	1 Li-Ion battery

Scooter	
Weight	~90kg
ICE type	Average 2ST and 4ST
Consumption	~2.8l/100km
Life expectancy	50000km
Maintenance	23% of plastic
	10% of steel
	10% aluminium
	tyres every 5000km

Electric and conventional cars

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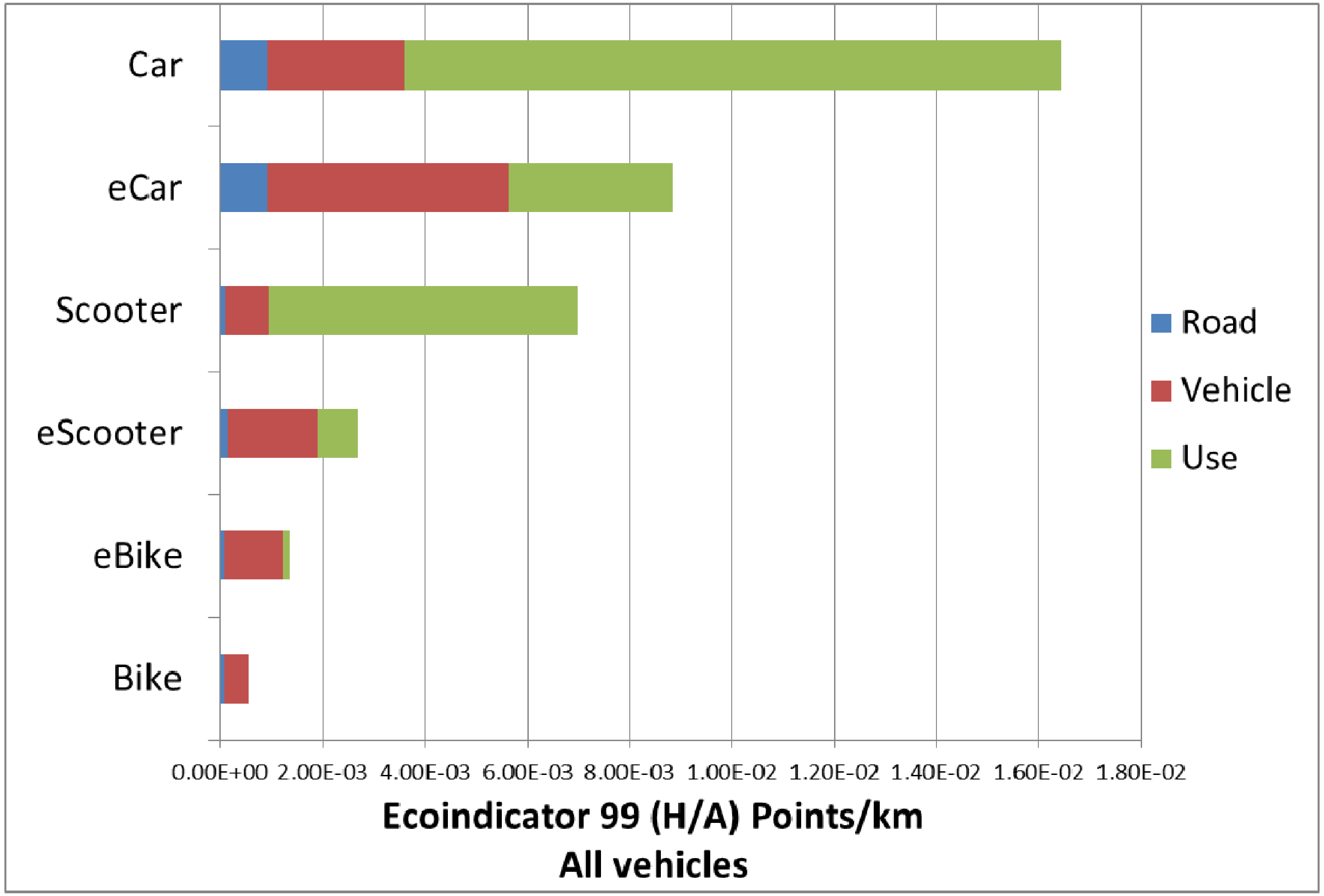
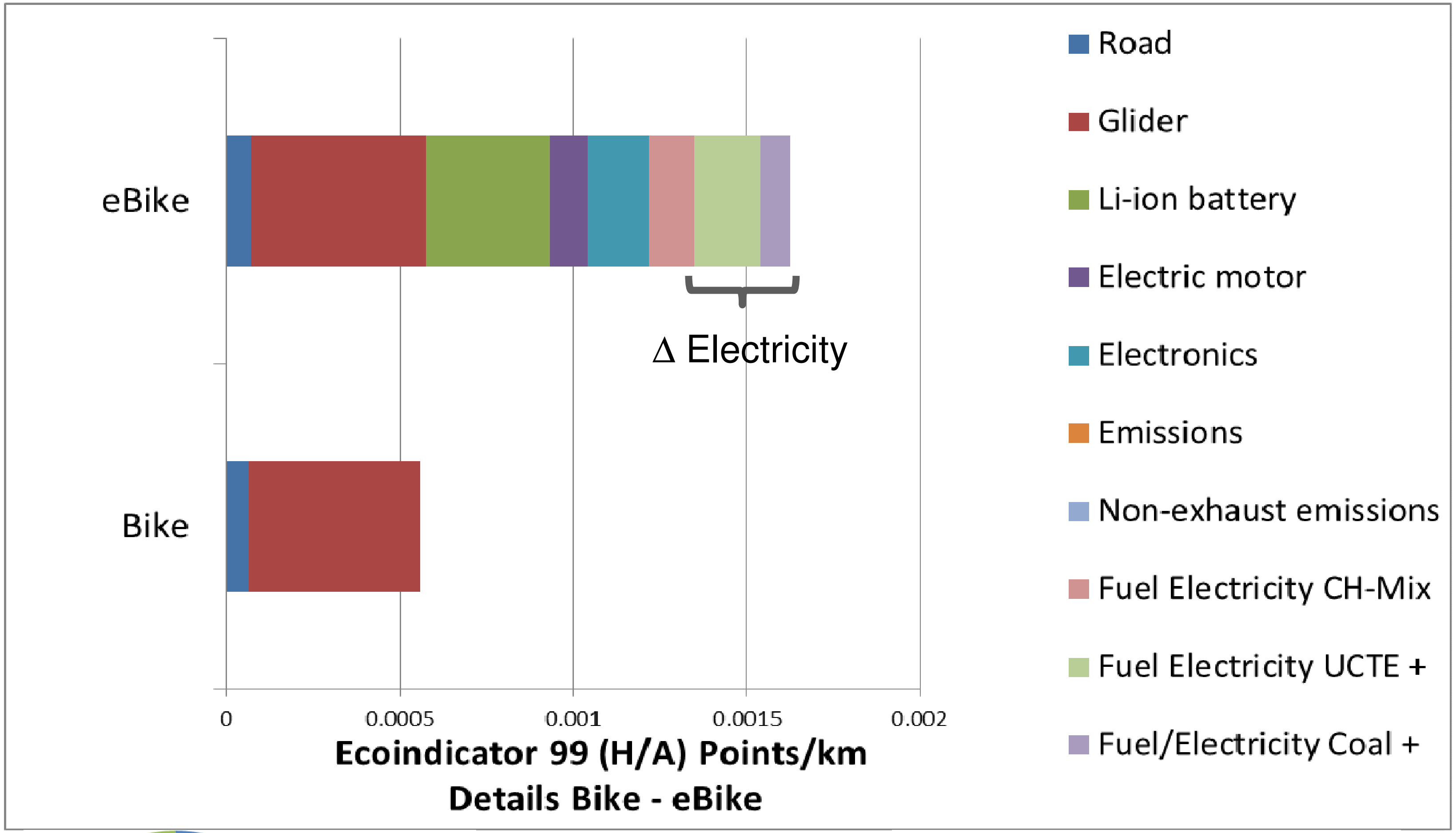
eCar	
Weight	1484kg
Li-Ion battery	400kg
Consumption	0.2kWh/km
Life expectancy	150000km

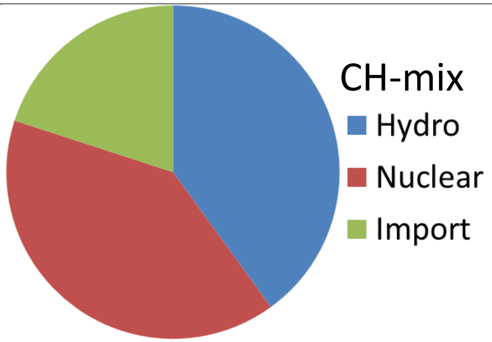
Car	
Weight	1234kg
ICE type	Petrol
Consumption	0.068l/km
Life expectancy	150000km

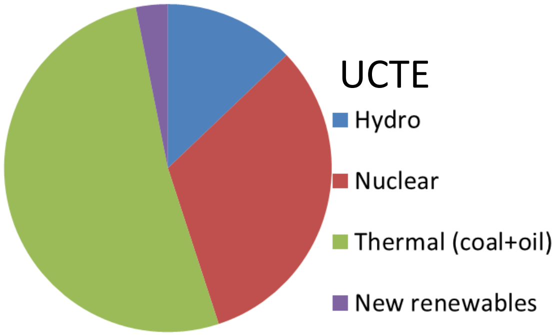
Ecoindicator 99 (H/A)



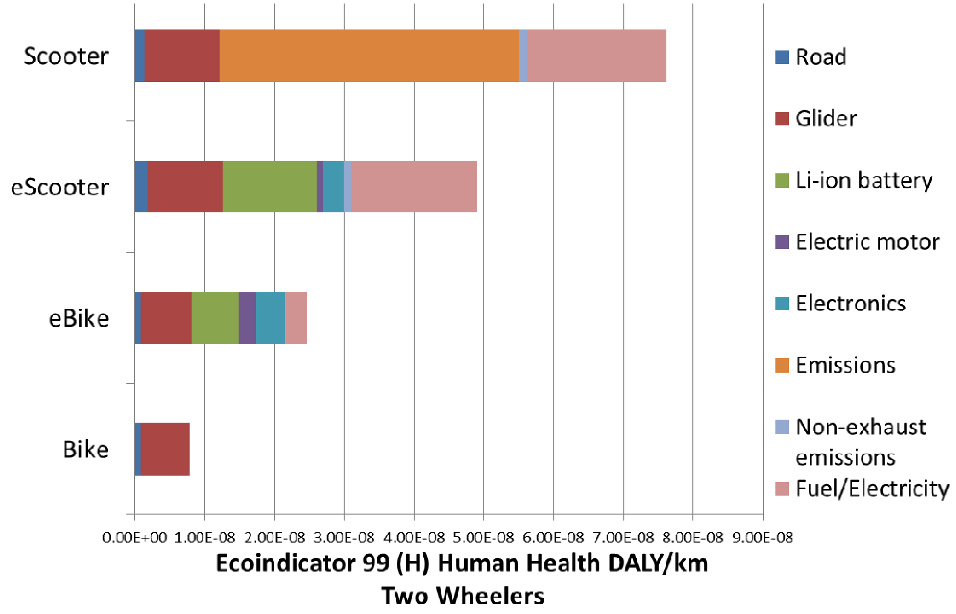
Ecoindicator 99 (H/A): Details Bike vs eBike

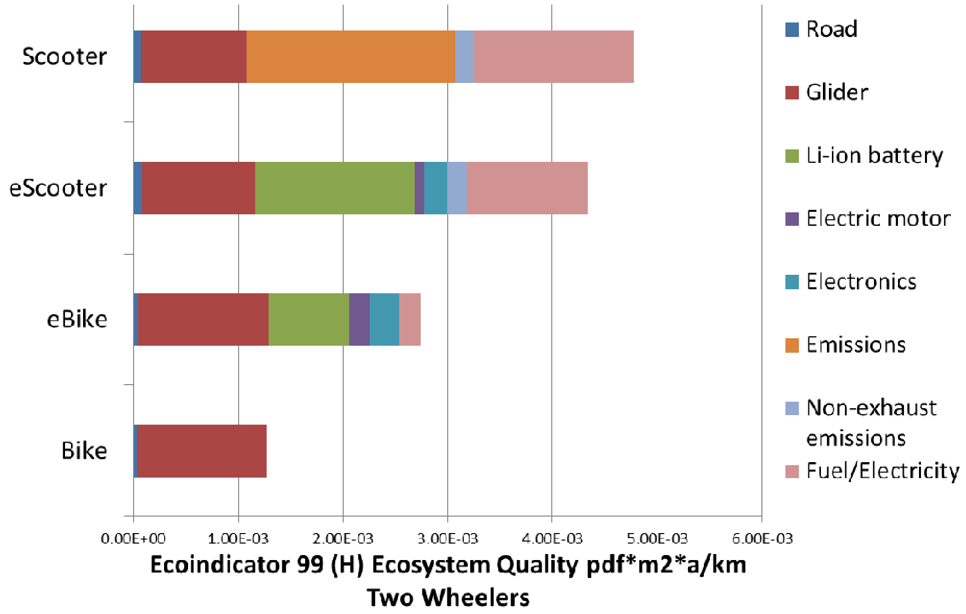


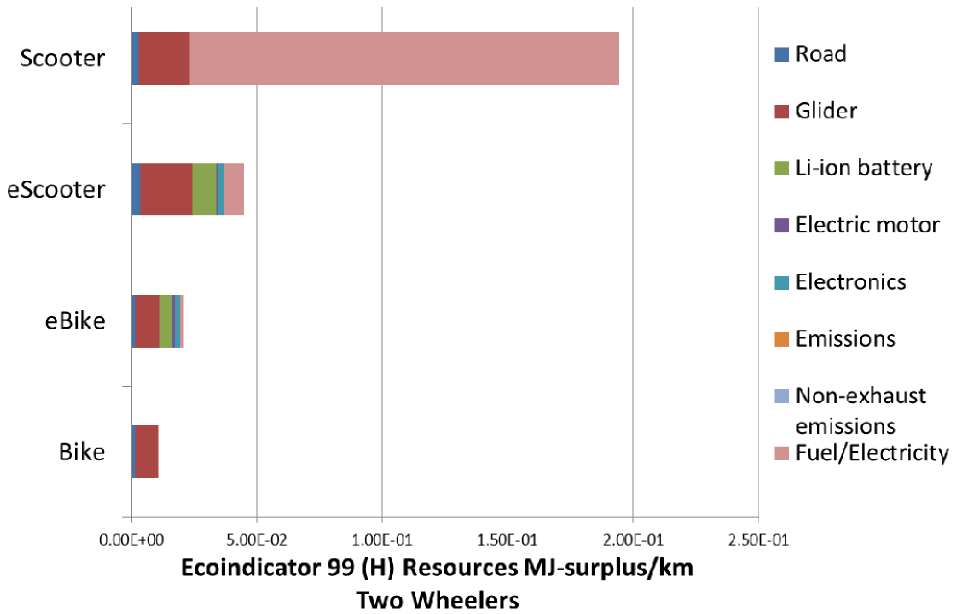




Ecoindicator 99







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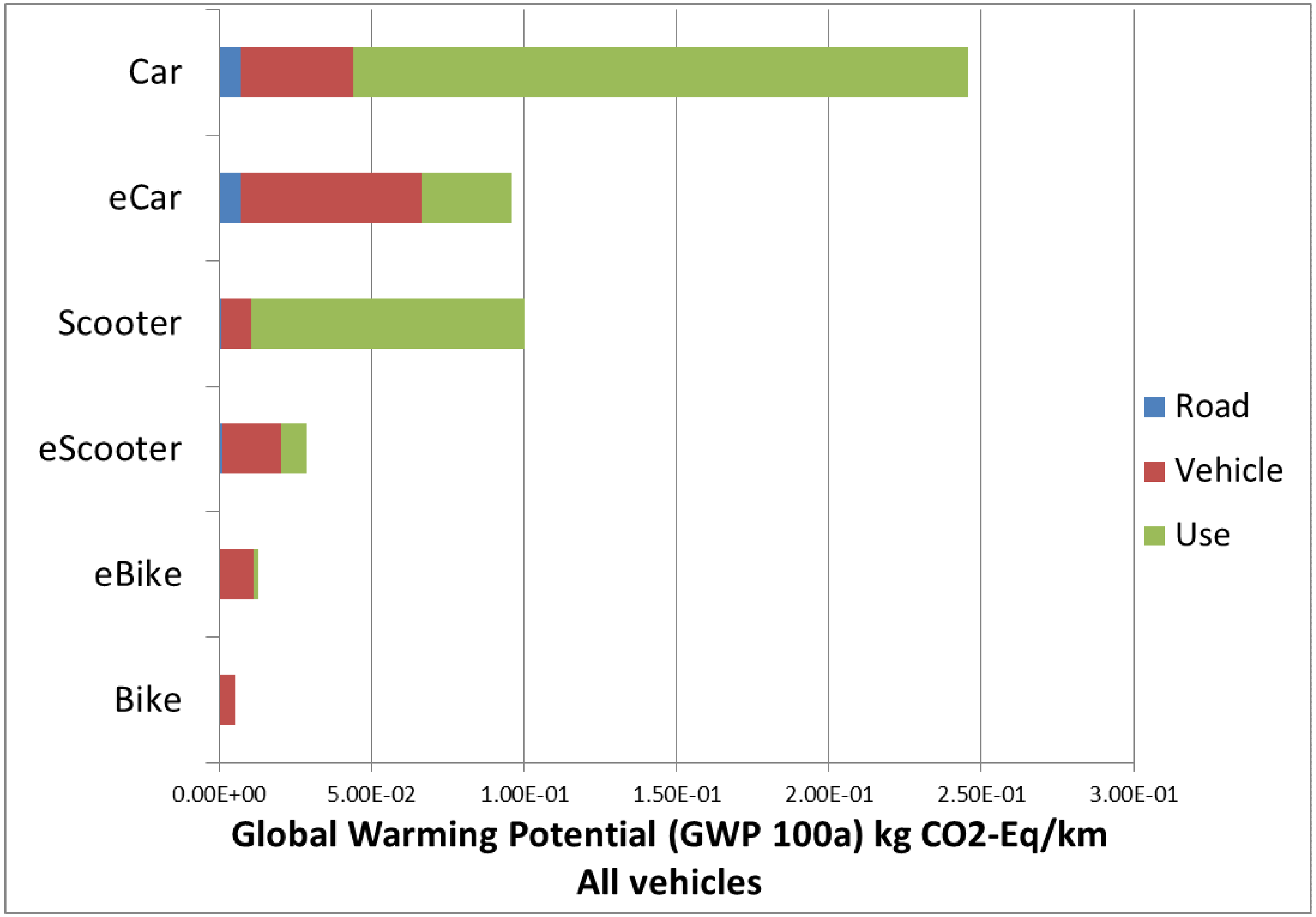
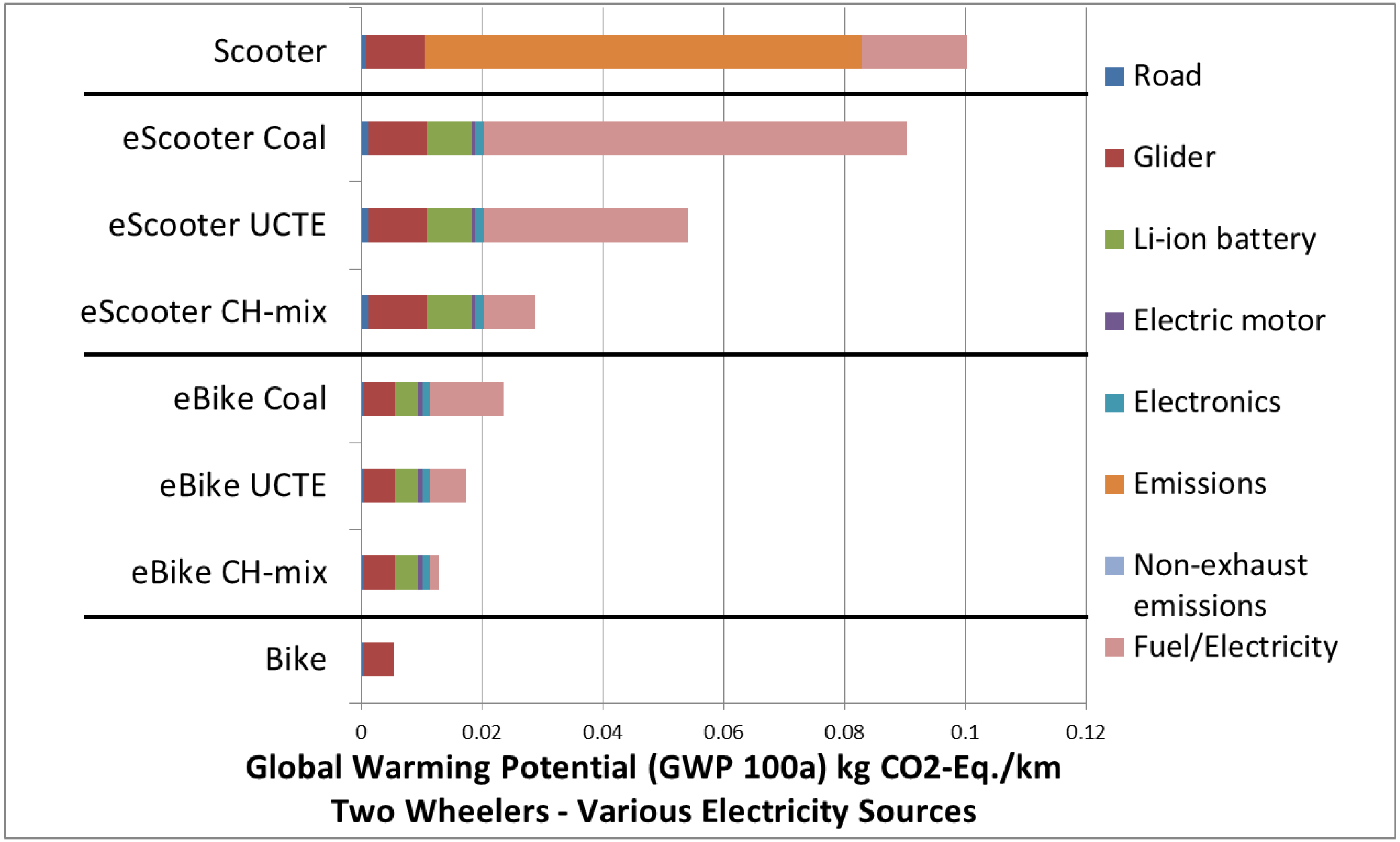
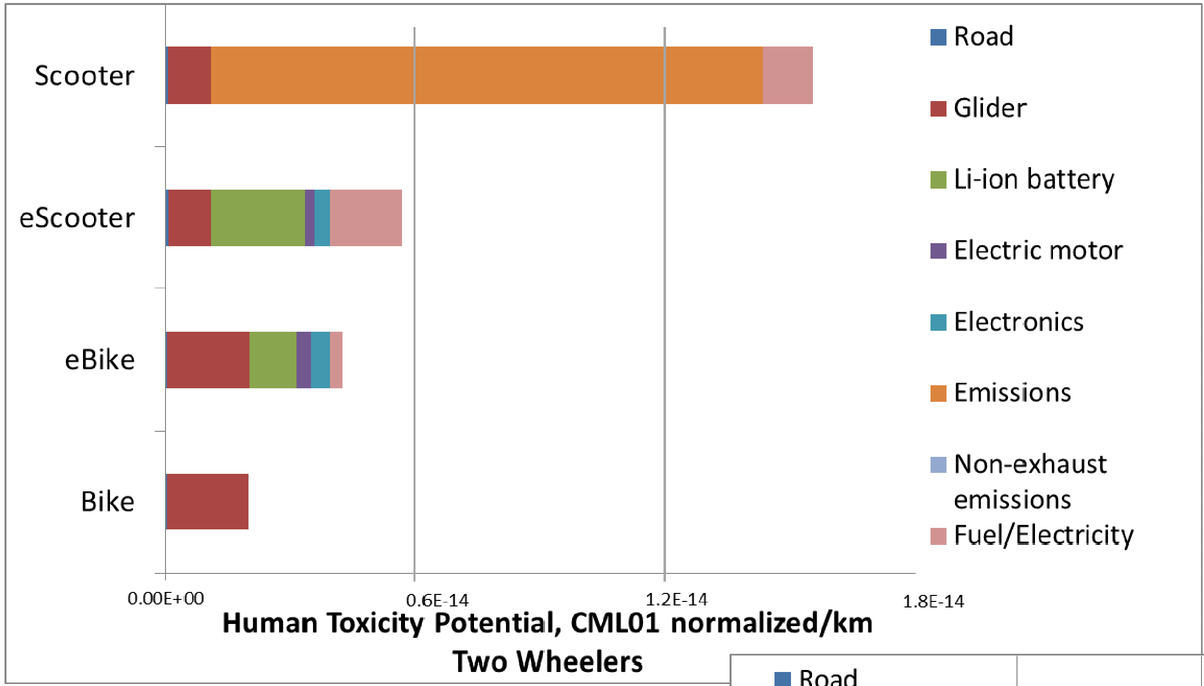
GWP – IPPC 2007 1

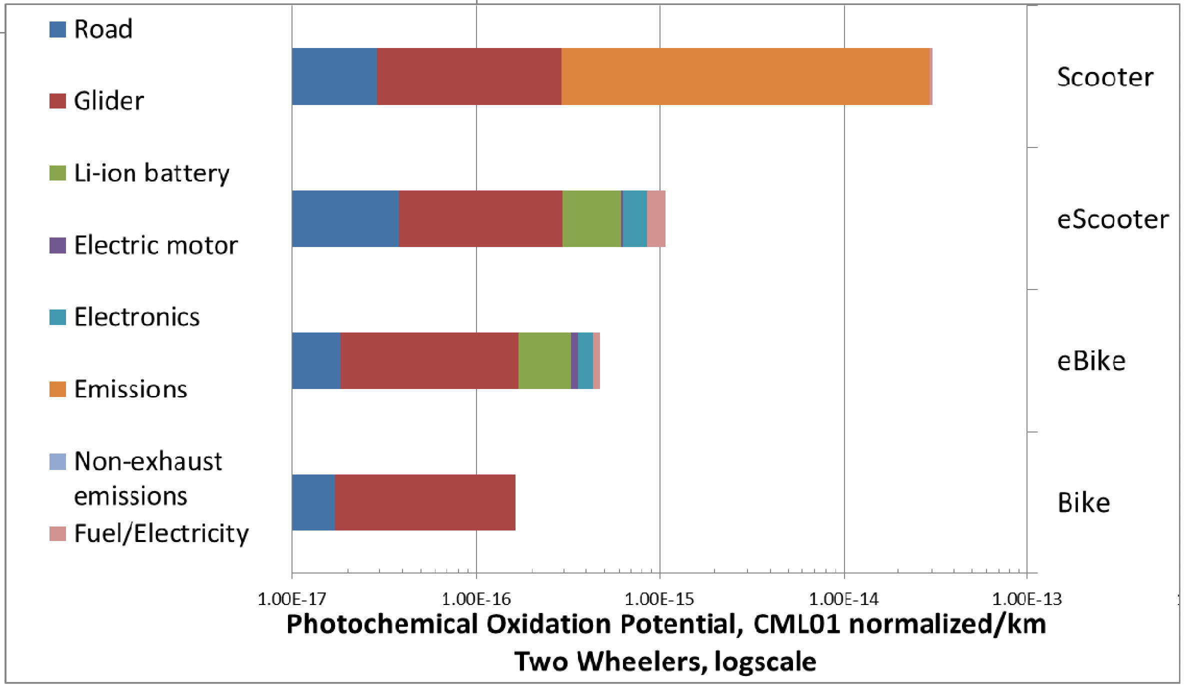


GWP – IPPC 2007 2

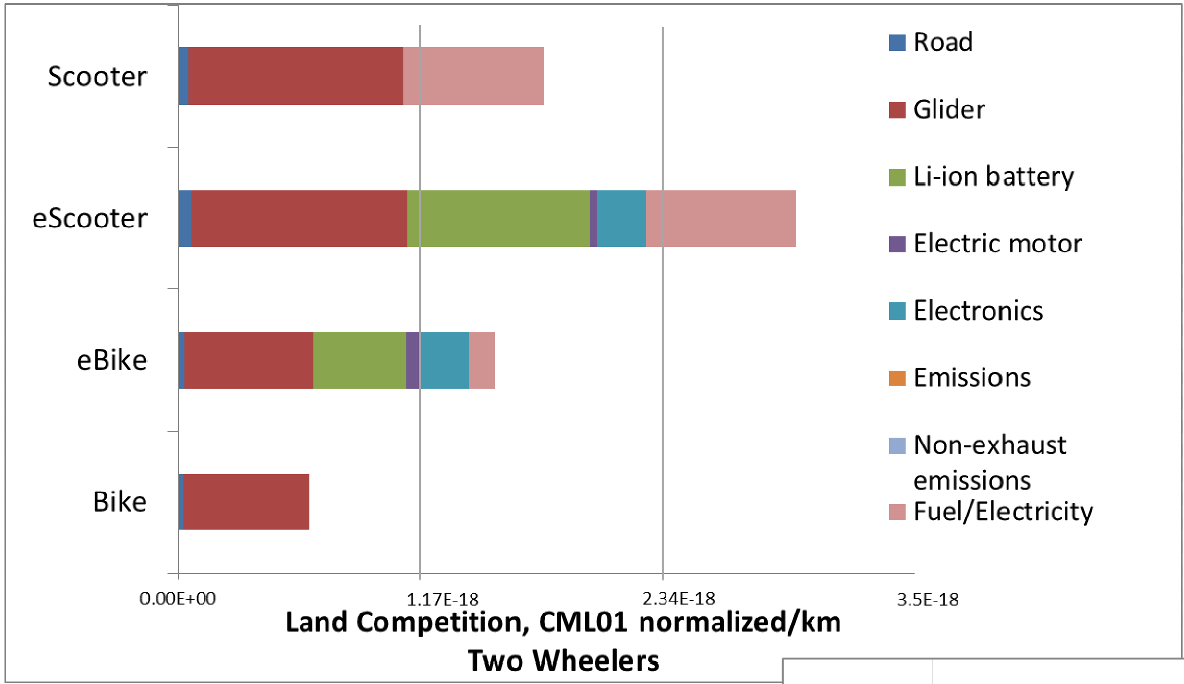


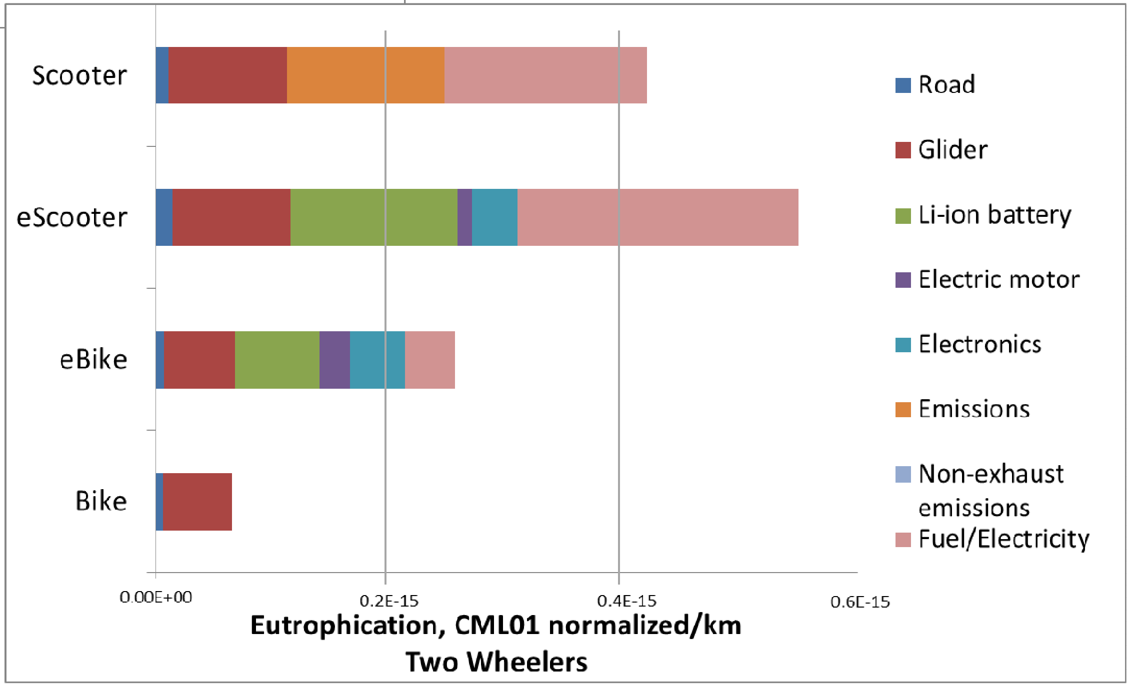
CML01 HTP and POCP



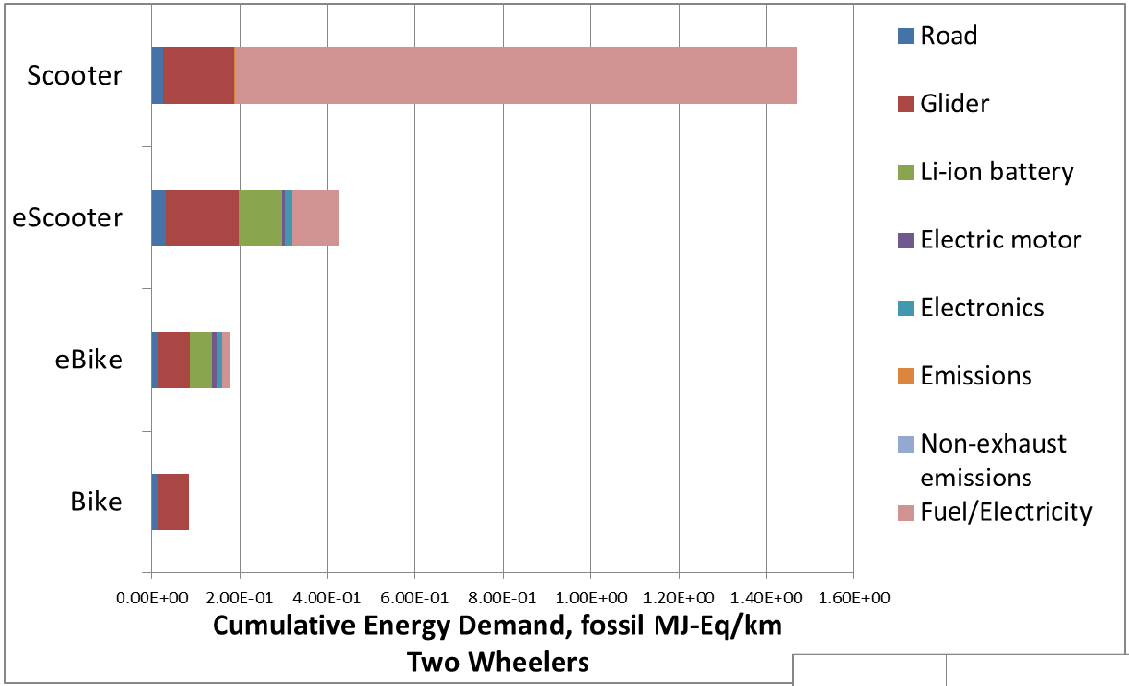


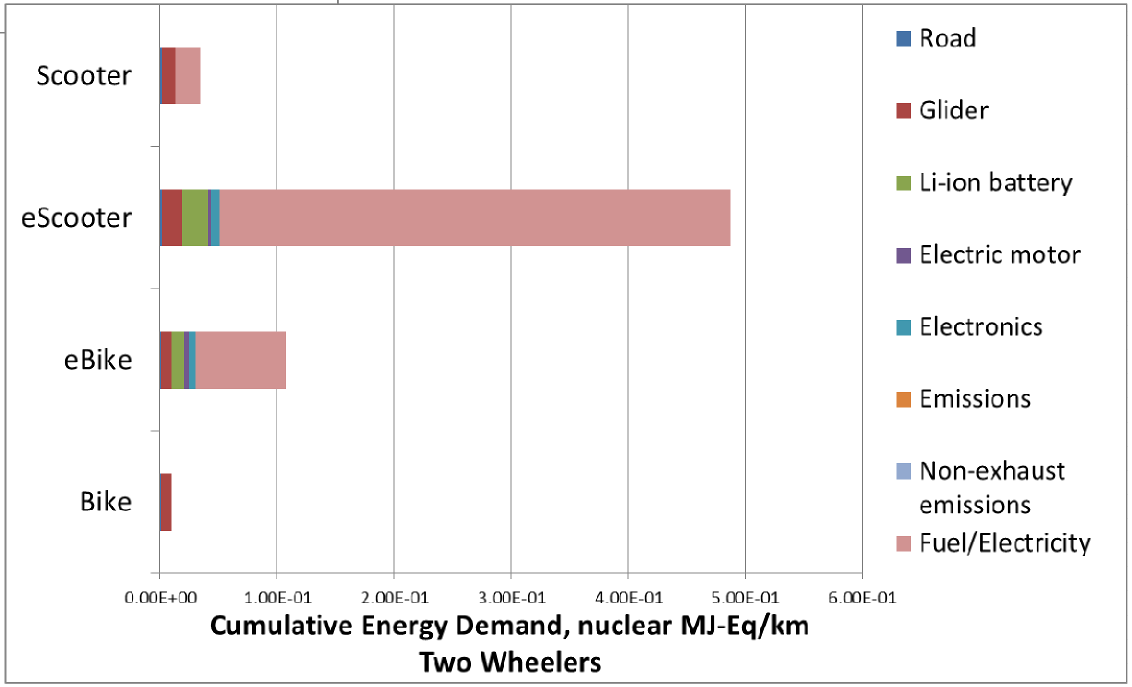
CML01 LUC and EP



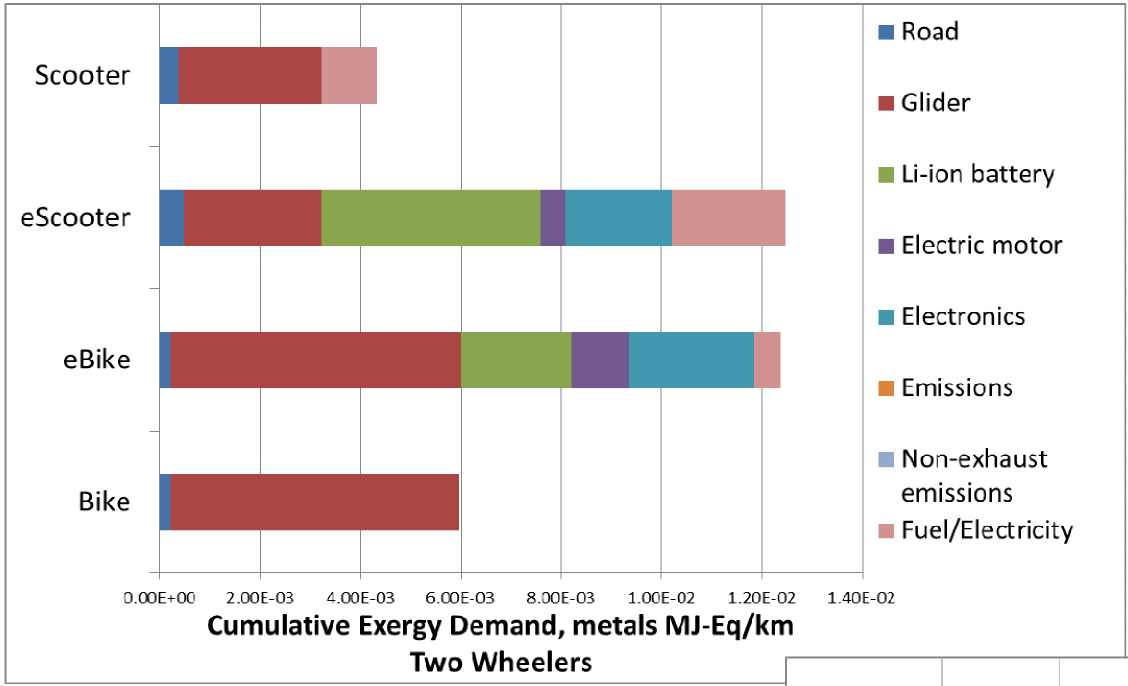


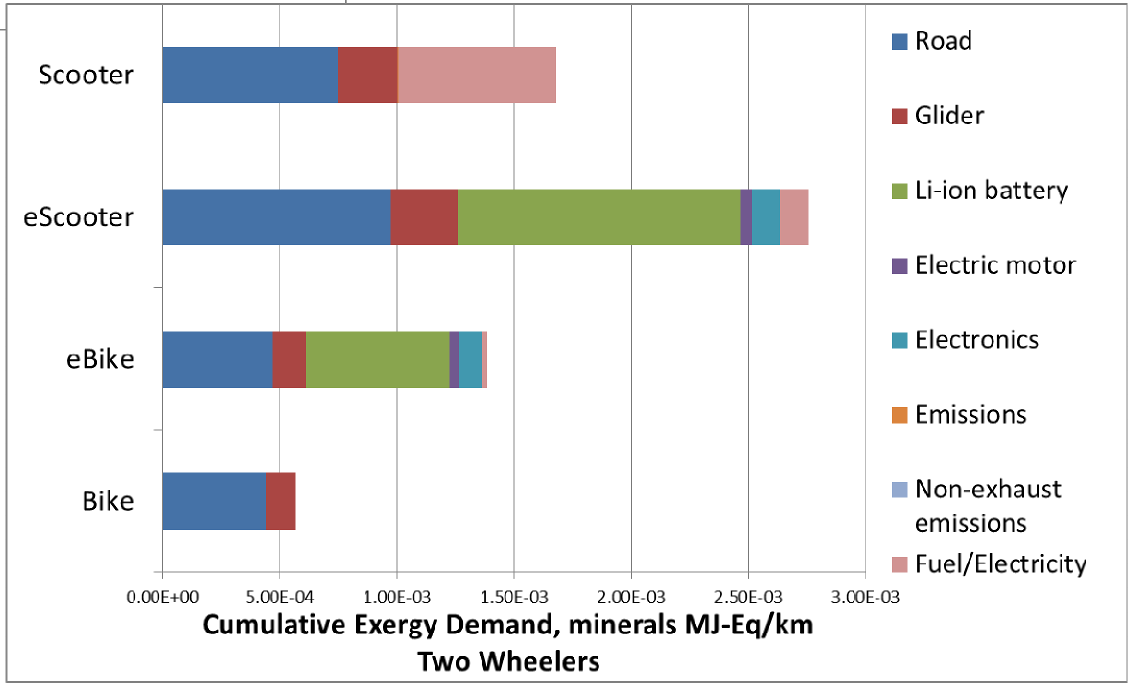
CED fossil and nuclear





CExD metals and minerals





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Conclusions

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- An electric bike causes larger impacts on the environment compared to a conventional one due to the added technology and resources needed: battery, electricity, electronics.
- The battery has a significant contribution on the overall impact of various indicators (copper mining and production). -> Importance of recycling schemes for batteries as well as electronics!
- Sustainable electricity for battery charging reduces the impacts caused during the use phase of electric bikes.
- For most indicators eBikes cause lower impacts compared to other motorized vehicles.

Thank you very much for your attention!

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- Questions?

Thanks to:

Fabienne Habermacher, Hans-Jörg Althaus, Marcel Gauch, Rolf Widmer.