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THELMA
TecHnology centered ELectric Mobility Assessment

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LCA COMPARISON OF ELECTRIC DRIVETRAINS IN PASSENGER CARS

Goals & Scope

Goals

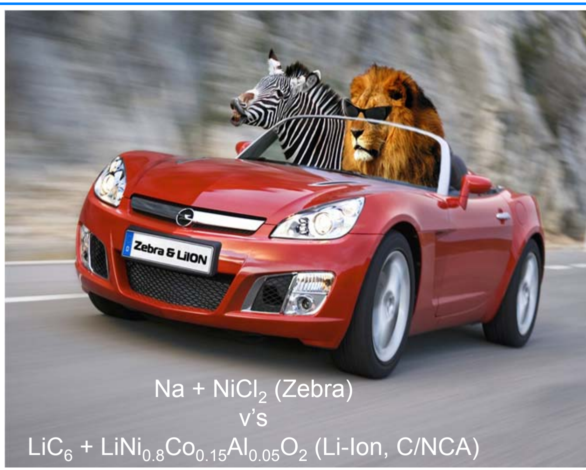
To compare:

- environmental performance of **electric v's conventional drivetrains**
- **different battery chemistries** for battery electric vehicles (BeV)
- **all electric** drivetrains v's fuel cell **electric** (FCe) drivetrain
- **energy chains**, including new inventories for H_2 production

Scope

- Life cycle inventories for the **production & operation of BeV, FCeV & ICEV**
- Vehicle end-of-life not yet adequately reflected
- Results for **resource uses and a range of emissions**
- Results relative to internal combustion engine vehicle (ICEV) of current average performance & average European driving conditions
- Differentiation between **global burdens** and **local / regional potential impacts**

Comparing battery chemistries



Characteristics of the battery electric vehicles

	With Zebra	With Li-Ion	
Range	**150**	**150**	**km**
Energy demand at wheels per 100km	**14**	**14**	**kWh**
Specific energy	119	**132**	Wh/kg
Max depth of discharge (DOD)	80	**80**	%
Battery efficiency (Charge/discharge)	84	93	%
Drivetrain efficiency (incl battery dischrg)	59	85	%
Grid to wheels efficiency	**56**	**82**	%
Rated energy (100% SOC)	48	41	kWh
Electricity demand per km	**0.28**	**0.20**	**kWh/vkm**
Vehicle weight	1530	1400	kg

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Electric drivetrains v's conventional

FCeV (H_2)	ICEV (Petrol)
	
Polymer Electrolyte Membrane (PEM) fuel cell + Li-Ion battery	<1.4 litres, EURO 5, average European performance.

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Characteristics of the petrol & fuel cell electric vehicle

	Petrol ICEV	Hydrogen FCeV	
Standard	**EURO 5**	**2010-15**	
Engine / fuel cell size	**<1.4 litres**	**100kW**	
Net power	**80**	**80**	**kW**
Range	730	500	km
Tank-to-Wheel efficiency	25	45	%
Fuel consumption per 100km	**6.3***	**3.4**	**litres petrol eq.**
Vehicle weight (as modelled)	1020	1130	kg
Hydrogen consumption	*(20-25)*	9	g/km
Battery for hybrid system		2	kWh

* Current European average consumption for this vehicle size. Best in class around 5.2litres/100km

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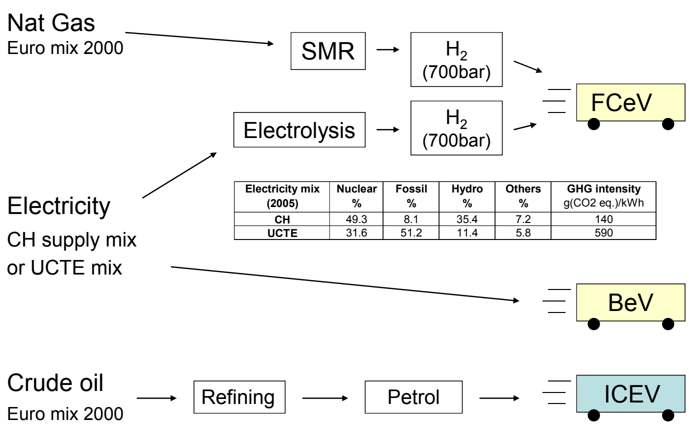
Fuel chains



Electricity mix (2005)	Nuclear %	Fossil %	Hydro %	Others %	GHG intensity g(CO2 eq.)/kWh
CH	49.3	8.1	35.4	7.2	140
UCTE	31.6	51.2	11.4	5.8	590

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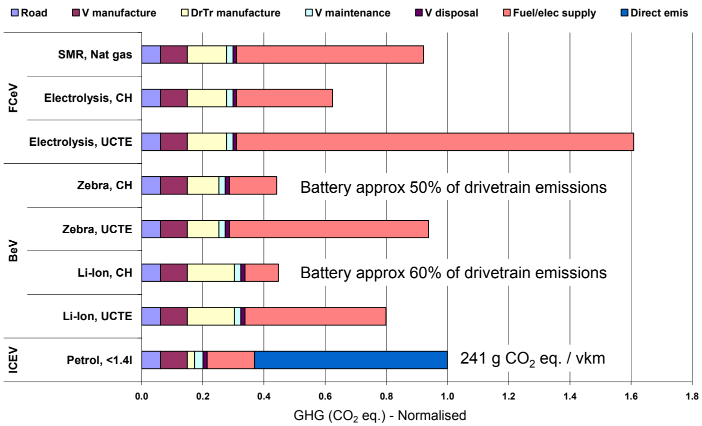
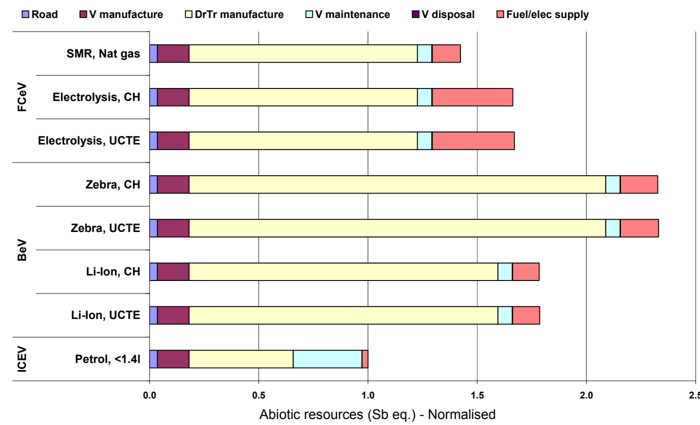
Assessment Methodology

Burden	Indicator	Description	Main substances
Global	Greenhouse gas (GHG) emissions. IPCC	**Global warming potentials** (GWP) of GHG calculated using CO_2 equivalent **GWP factors** (IPCC)	CO_2, CH_4, N_2O, SF_6, HCFC's
	Abiotic resource depletion. CML	**Scarcity of extracted metal ores.** Single metals expressed in mass of **antimony (Sb)-equivalents**	Cu, Fe, Mo, Pt, etc.
Local & regional	Acidification & Eutrophication. EI99	**Potential impacts on biodiversity.** Potentially disappeared fraction (PDF) of species **due to altered pH and nutrient levels**	NH_4, NO_x, SO_x
	Ecotoxicity. EI99	**Potential impacts on biodiversity.** Potentially affected fraction (PAF) of species **due to toxic emissions**	HM's, POP's, HC's
	Respiratory inorganics EI99	**Potential direct & indirect health impacts.** Uses the Disability Adjusted Life Year (DALY)	PM, NO_x, SO_x

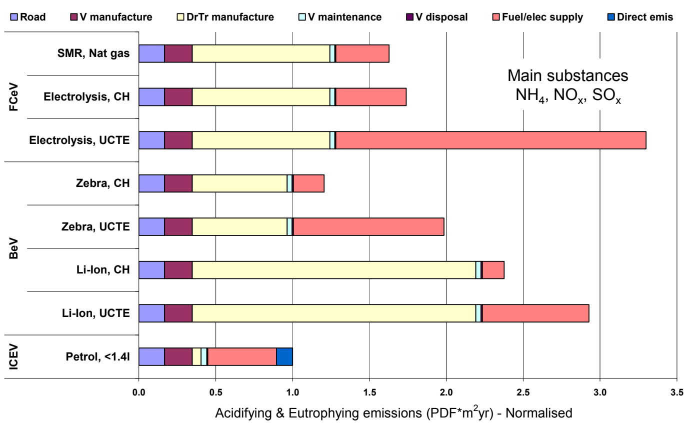
Global: GHG emissions



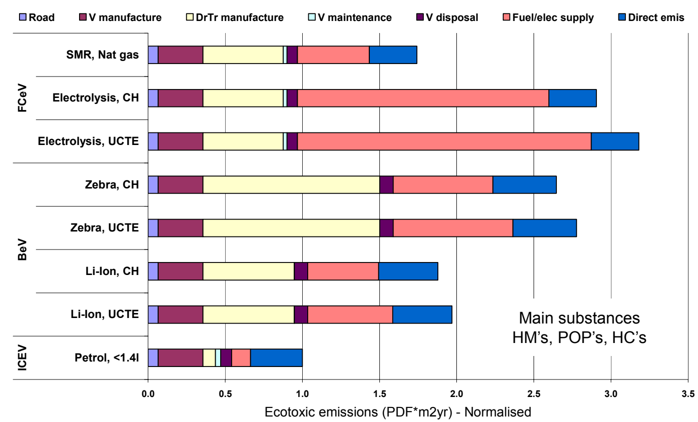
Global: Abiotic resources



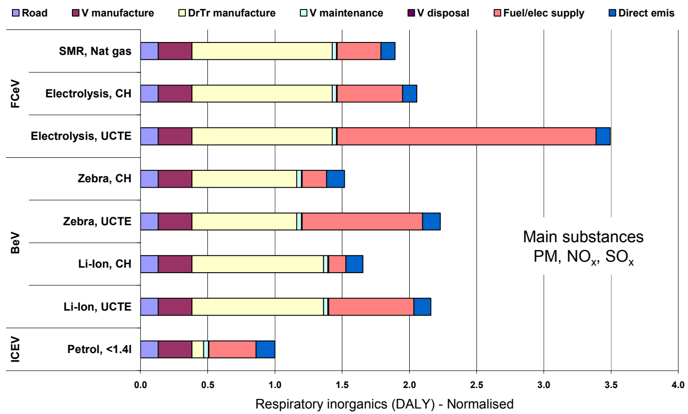
Local/Regional: Acidification & Eutrophication



Local/Regional: Ecotoxicity



Local/Regional: Respiratory inorganics



Conclusions: Global level

GHG emissions

- BeV's require a very low GHG intensive electricity source. Battery choice is then not so relevant.
- With lower drivetrain efficiency, FCeV are even more influenced by GHG intensity of H_2 source.
- Battery or fuel cell: no great differences between production emissions.

Abiotic resources

- Shift to electric drivetrains means a shift in resource competition – Vehicle EOL
- Most influential are elements used in electronics for both BeV & FCeV, also Platinum in FCeV

Conclusions: Local / Regional level

Acidification / Eutrophication & Ecotoxicity

- Electric drivetrains may increase burdens on ecosystems - emissions from mining & processing of resources (metals and fuels), and the combustion of fossil fuels in background processes.
- Production of the batteries and fuel cell are defined by location and energy inputs but emissions & potential impacts are generic – future work to consider differences between production locations.

Human health

- Modern ICEV have low exhaust emissions: much of the burdens are non-exhaust – so similar to BeV & FCeV.
- Potential health impacts due to the emissions from mining & processing of resources (metals and fuels), and the combustion of fossil fuels are very dependant on regional population and their exposure – THELMA to consider.

Thank you for listening

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