Capacity Area B2 Topic 2.2 Milestone 1

Sustainability indicator database

The purpose of multi-criteria decision analysis (MCDA) is to aid decision makers in finding their own best strategies and to inform and assist debate between multiple stakeholders. It does this by providing an analytic structure that can help decision makers and stakeholders overcome the inherent cognitive limitations present when there are trade-offs between too many different criteria for too many alternatives. In order to evaluate the relative sustainability of the technological options their performance on environmental, economic and social criteria (represented by the corresponding quantitative indicators) are combined with preference profiles of stakeholders and decision makers. MCDA is more than just choosing an appropriate algorithm for solving a specific type of problem. Instead, it is best used as part of a complete process to inform and assist decision makers.

At this stage, MCDA was carried out for mid class cars for a variety of drivetrains, fuels, electricity inputs for battery cars and different means of hydrogen production for fuel cell cars. The basic technology characterizations as well as four environmental indicators (climate change, non-renewable primary energy, metal depletion and impact on ecosystems) origin from life cycle assessment (LCA). Eight additional indicators were quantified, including two economic (purchase cost and ownership lifetime cost), four social (health impacts from normal operation, expected mortality due to severe accidents in the supply chain, maximum number of fatalities in severe accidents in the supply chain representing risk aversion, and noise) and two representing utility (range and charging/fueling time).

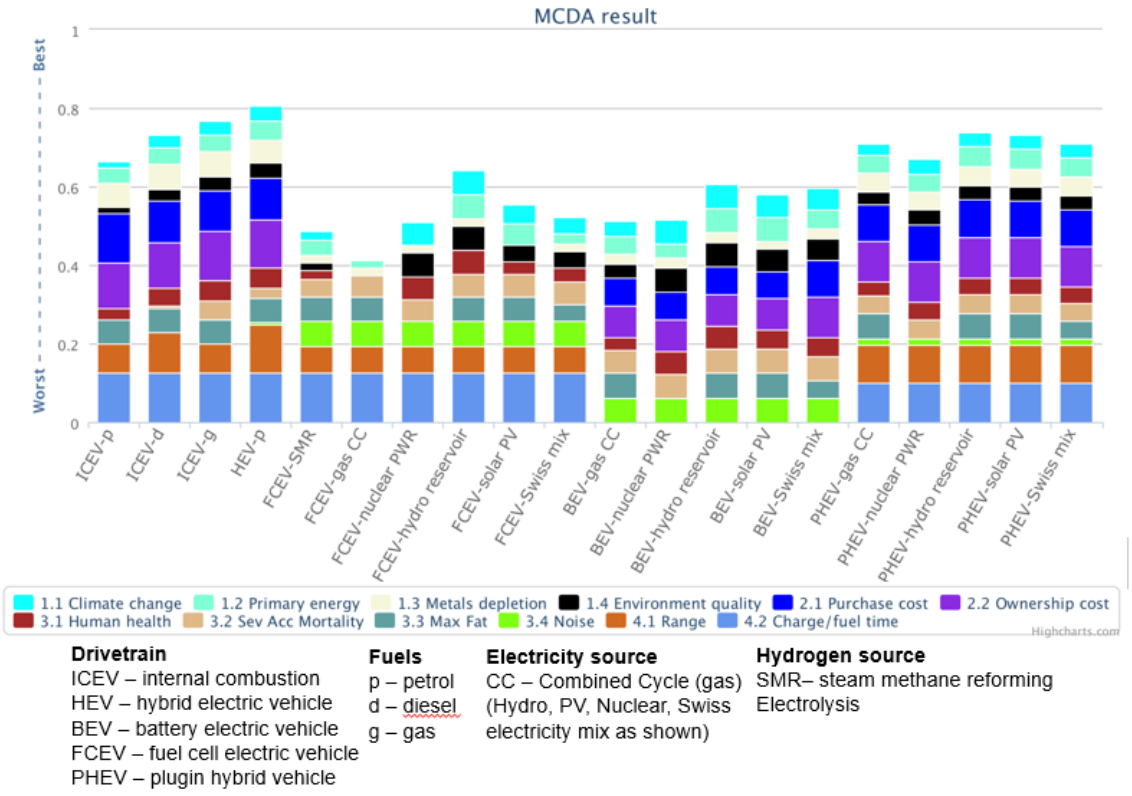
The approach and MCDA tool developed by us allow in principle to quantify the corresponding indicators for many combinations of vehicle characteristics (size classes, performance levels such as ranges, powertrains, fuel types, operating conditions, time points, fuel prices and a large variety of options for electricity supply and hydrogen production).

Figure 1 shows the results for current car technologies (reference year 2018) using equal weights for all the criteria and employing a simple weighted sum approach for MCDA aggregation. Under such homogeneous profiles the best performer is hybrid car with petrol followed by gas car, plugin hybrids and diesel car. The best performers among electric cars are fuel cell vehicle with hydrogen produced using hydro-electricity and battery cars with electricity originating from hydro, solar photovoltaic (PV) or the Swiss electricity mix.

If the preferences are totally focused on minimizing emissions of greenhouse gases and consumption of non-renewable energy, i.e. the primary goals of the energy transition, then the ranking changes radically as shown in Figure 2. Fuel cell cars with hydrogen produced using hydro and battery cars with electricity supplied by hydro or solar PV become superior to all cars using fossil fuels.

Sensitivity mapping based on different preference profiles shows that for current cars under the Swiss conditions the emphasis on environment and social aspects is favorable to electric cars while emphasis on economy currently works to the advantage of fossil cars; emphasis on utility penalizes battery cars.

The corresponding analyses are pursued for the future car technologies (reference year 2040) and for the future car fleet. We also aim at performing MCDA for trucks and for public versus individual transport options. The impact of using alternative algorithms for MCDA will be explored.



Drivetrain
ICEV – internal combustion
HEV – hybrid electric vehicle
BEV – battery electric vehicle
FCEV – fuel cell electric vehicle
PHEV – plugin hybrid vehicle

Fuels
p – petrol
d – diesel
g – gas

Electricity source
CC – Combined Cycle (gas)
(Hydro, PV, Nuclear, Swiss electricity mix as shown)

Hydrogen source
SMR– steam methane reforming
Electrolysis

Figure 1. MCDA results for current (2018) mid-size cars using equal weights for all indicators.

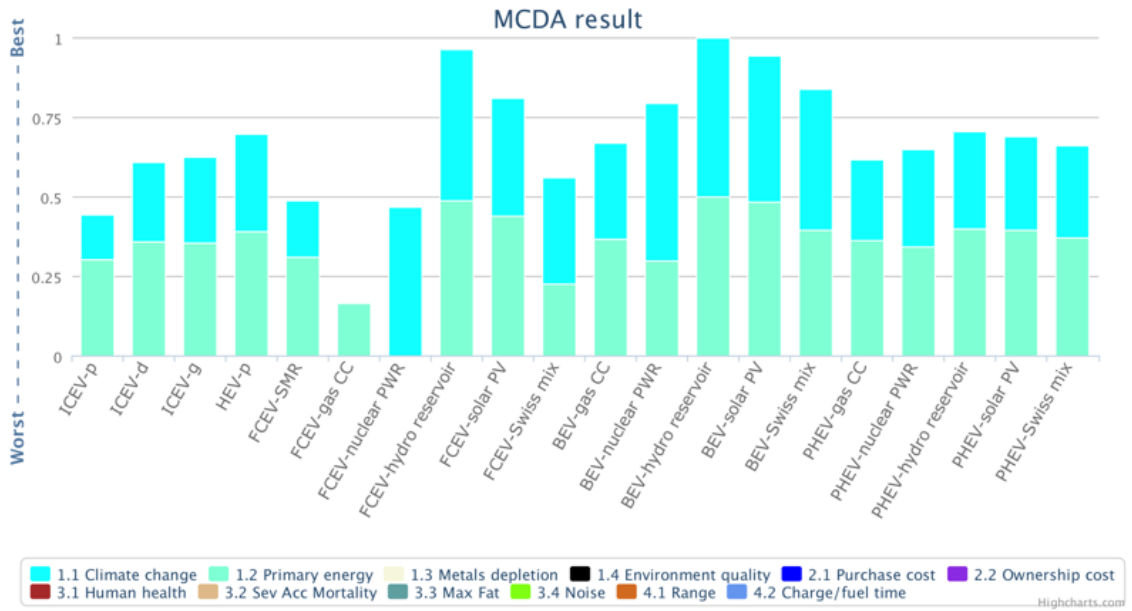


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Figure 2. MCDA results for current (2018) mid-size cars based on 100% prioritization of primary goals of energy transition, i.e. climate protection and energy efficiency.