LIFE CYCLE ANALYSIS OF PHOTOVOLTAIC-SUPPLIED "SOLAR FILLING STATIONS" FOR ELECTRIC PASSENGER VEHICLES

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This presentation has been elaborated from the results of the concluded project "Environmental Precaution Study for Research Projects (EPS) - Demonstrated at the Example of Photovoltaics".

The objective of this project is the development of a methodology to assess potential environmental impacts of technologies under development for the case of their large scale market introduction. The EPS assessment approach is an alternative comparison of environmental impacts by substance emission on the one side from existing wide spread techniques (e.g., passenger vehicles, power plant systems etc.) versus the novel technology under consideration in the case of an assumed wide spread implementation.
As appropriate examination approach the life cycle analysis-LCA has been chosen, in principle allowing the compilation of all emissions at all levels of a product utilization. But EPS goes beyond that: The result of a LCA is a more or less comprehensive list of substances discharged into environmental compartments (here identified as atmo-, hydro- and pedosphere). But for evaluating comparisons something like "common denominators" is required to allow the addition and aggregation of environmental burden factors.

The selected approach for EPS identifies three different value systems:
o limit threshold and orientation values
o toxicological values
o ecotoxicological values.

Specifically they comprise 2 limit thresholds and 1 orientation value for air pollutants, and 2 ecotoxicity and 3 genotoxicity value systems. Additionally also the solid waste volume and the total CO_2-emissions, and the primary energy expenditures are included as evaluation criteria.
Health and safety issues associated with the production of PV-modules are not the scope of the EPS.

As study case an emission comparison is presented for an entirely electric passenger car (EPC)-based daily occupational short distance transportation (OSDT) (from home to work and back), their batteries powered by public grid connected PV-panel stations at the occupational parking places ("solar service stations"), versus advanced conventional fuel powered passenger cars (FPC) with three-way-catalysts (TWC), presumptive technology status of the year 2005, but mileage of 1987 (90,4 billion Pkm). The technology status is defined via the emissions per passenger kilometer (Pkm) of CO_2, CO, NO_x, SO_2, HC, particulates. Estimations are made for the replacement of the FPCs for the OSDT of the old FRG (West-Germany) by EPCs with (partial) solar PV-supply, the uncovered demand provided by the public utilities grid. The nonconsumed solar electricity in this model of "solar EPC-service stations" is supplied to the public grid (in off-demand periods) and the surplus demand is provided by the public grid and the evaluation is based on an annual balance.
The presumptive status of the year 2005 is defined for two scenarios "Trend" and "Reduction" of a study initiated by the Parliamentary Enquete Commission of the German Federal Assembly (Bundestag) "Precaution for the Protection of the Global Atmosphere". Additionally , also the Öko-Polo of Volkswagen (VW) as future Diesel-powered small "saving" car version with a low power (25 kW) in the power range of EPCs is included.
In detail the following assumptions were made, according to a type of "benchmark" approach, i.e. to take maximum and minimum values of parameters:

- o 2 sizes of EPCs:
  - 35 kWh(el)/100 Pkm "large"
  - 15 " " "small"

  The figures are to be regarded as annual mean values.
- o 3 types of Si-based modules (with their module efficiencies):
  - classical multicristalline η = 9,6 %
  - MIS-I-monocristalline η = 12,5 %
    (MIS-I = metal-insulator-semiconductor inversion layer)
  - amorphous η = 6,0 %
- o The idea of the PV-panels on the sites of the companies parking areas is a flat fixation on supporting structures parallel to ground. 2 alternative variants were considered:
  - a standard but optimized 2-pillar support as realized in German PV-demonstration fields
  - a light membrane system fixed with a guy rope structure.

9 alternative "variants" have been defined for the coverage of the annual 90,4 billion Pkm for the year 2005:

- o 3 conventional passenger vehicles types:
  "Trend", "Reduction", Öko-Polo (alternatively!)
- o 2 electric passenger vehicle types:
  "Large" (35 kWh/100 Pkm), "small" (15 kWh/100 Pkm)
  - 2 ways of demand coverage:
    - o grid supplied (EPC "small", EPC "large)
    - o PV and grid supported ("solar service stations")
      - • conventional multicristalline or amorphous Si-modules for the "large" EPCs, 2-pillar support
      - • amorphous or MIS-I-monocristalline Si-modules for the "small" EPCs, membranes with guy ropes.

Reference situation is the emission standard of the passenger vehicles in the year 1987.

Three sorts of variant assessments are made (based on annual mean values):

1. Comparisons of discharge quantities (standard pollutant emissions into the atmosphere comprising CO_2, CO, HC, NO_x, SO_2, dust).
2. Primary energy expenditures (their emissions included under item 1.)
3. Comparisons of 15 types of evaluation criteria via absolute and relative burden values (in percentages of the respective absolute maximum value of the worst case variant for each burden) as sums per compartment of addable impact factors of individual pollutants into the considered compartment, i.e. atmo-, hydro- or pedosphere.

The conclusions drawn subsequently are oriented towards general evaluations:

1. The polar diagrams of relative burden values demonstrate clearly the positive environmental relief relevance of silicon based PV, at least in case of replacement of fossil fuel based alternatives.
2. To substitute PV for substances emitting technologies is environmentally relieving, but PV is via its manufacturing processes not a zero emitter. (These specific values were the focus of data collection of the presented EPS-project).
3. PV for energy economically relevant application makes only sense with high efficiency modules. Current status of amorphous Si (n < 6 %) seems inappropriate.

4. Supportive structures should be as light as possible with minimized material requirements. Their fabrication emissions can be substantial, e.g. for steel. Integration into facades and roofs of buildings or membranes with guy rope systems seem preferable with respect to pillar support.
5. In order to allow for solar supply shares as high as possible in any PV-application with conventional back-up-systems the electricity demand should be minimized in the sense of rational use of energy. This is especially significant for the primary energy balance of electric vehicles versus fuel powered vehicles.