A Parameterized Model for the Estimation of Life-cycle Environmental Impacts of Crystalline PV Systems

EU PVSEC
European PV Solar Energy Conference and Exhibition

Centre O.I.E.

Observation, Impacts, Energie
(Sophia Antipolis, France)

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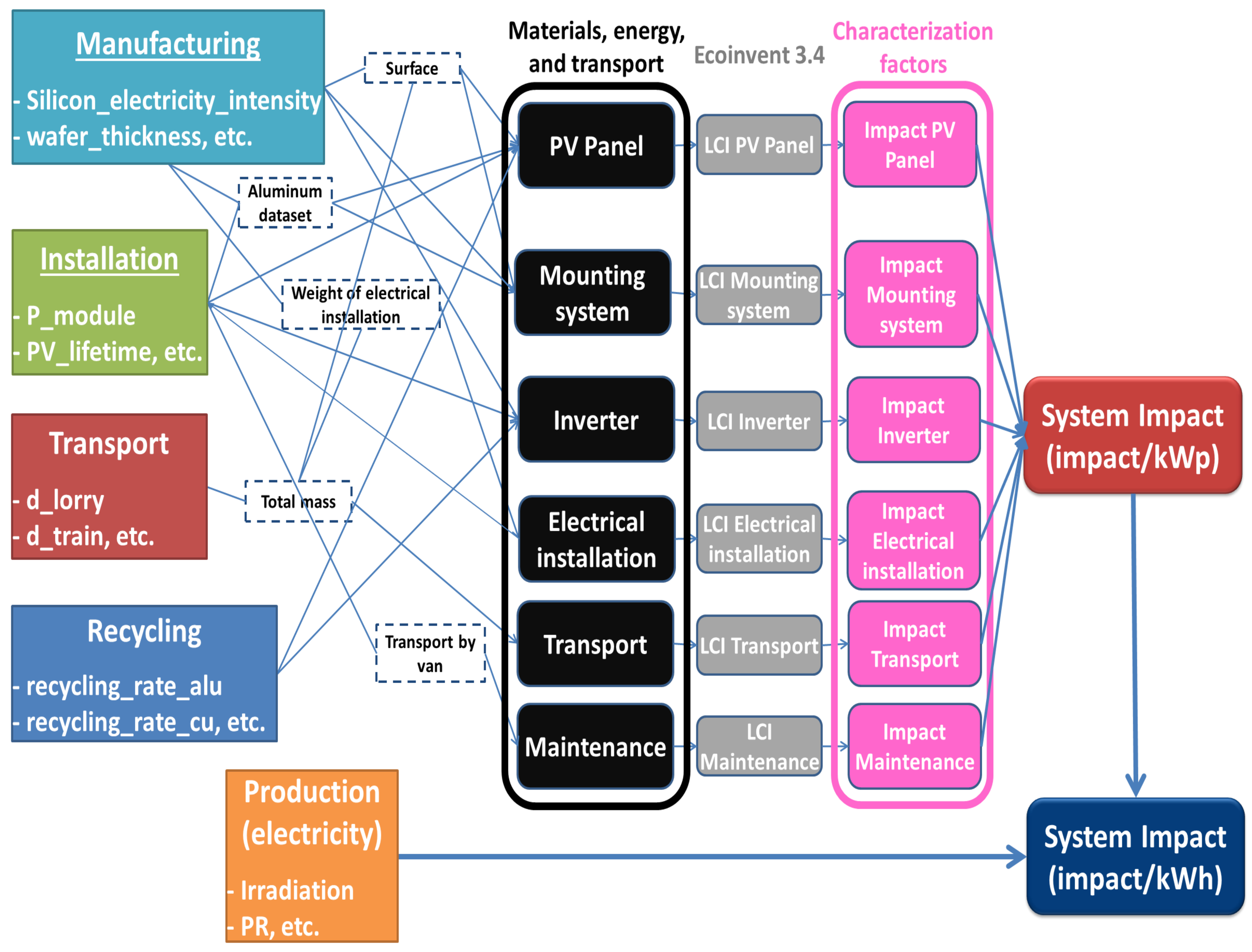
Introduction & Objective

- The integration of renewable energy systems is expected to contribute by 36% to the reduction of carbon related emissions.
- Silicon-based photovoltaic (PV) technologies dominate the PV systems market with a share of 95% of the total production in 2017.
- 80 – 90 % of environmental impacts of these systems are associated with manufacturing stages where large technological, geographical, and methodological variabilities, 30-80 g-CO_2-eq/kWh, are present.
- The aim is to offer a tool allowing the flexibility to analyze environmental impacts of a wide range of PV systems by using an explicit up-to-date Life Cycle Assessment (LCA) parameterized model.

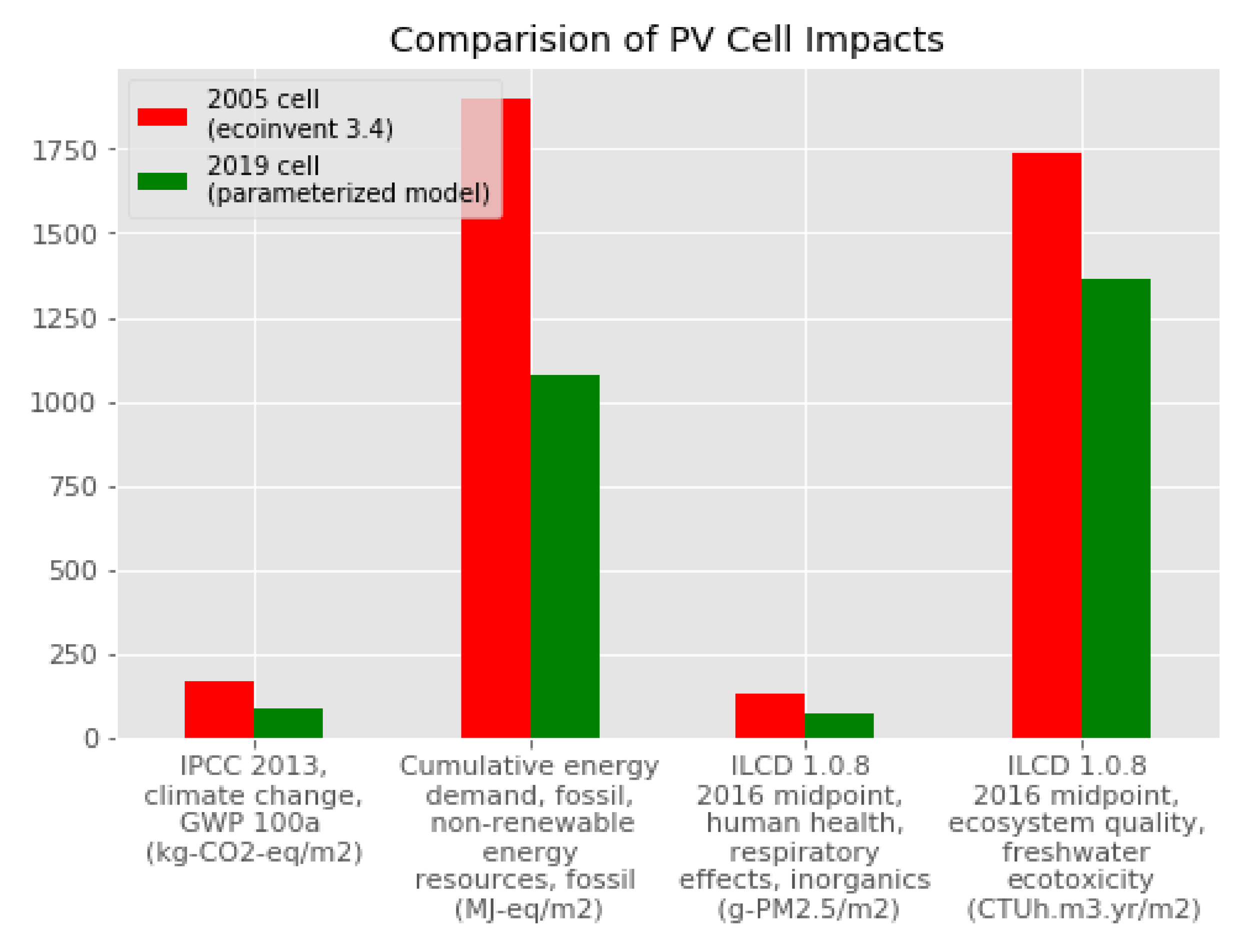
Materials & Methods

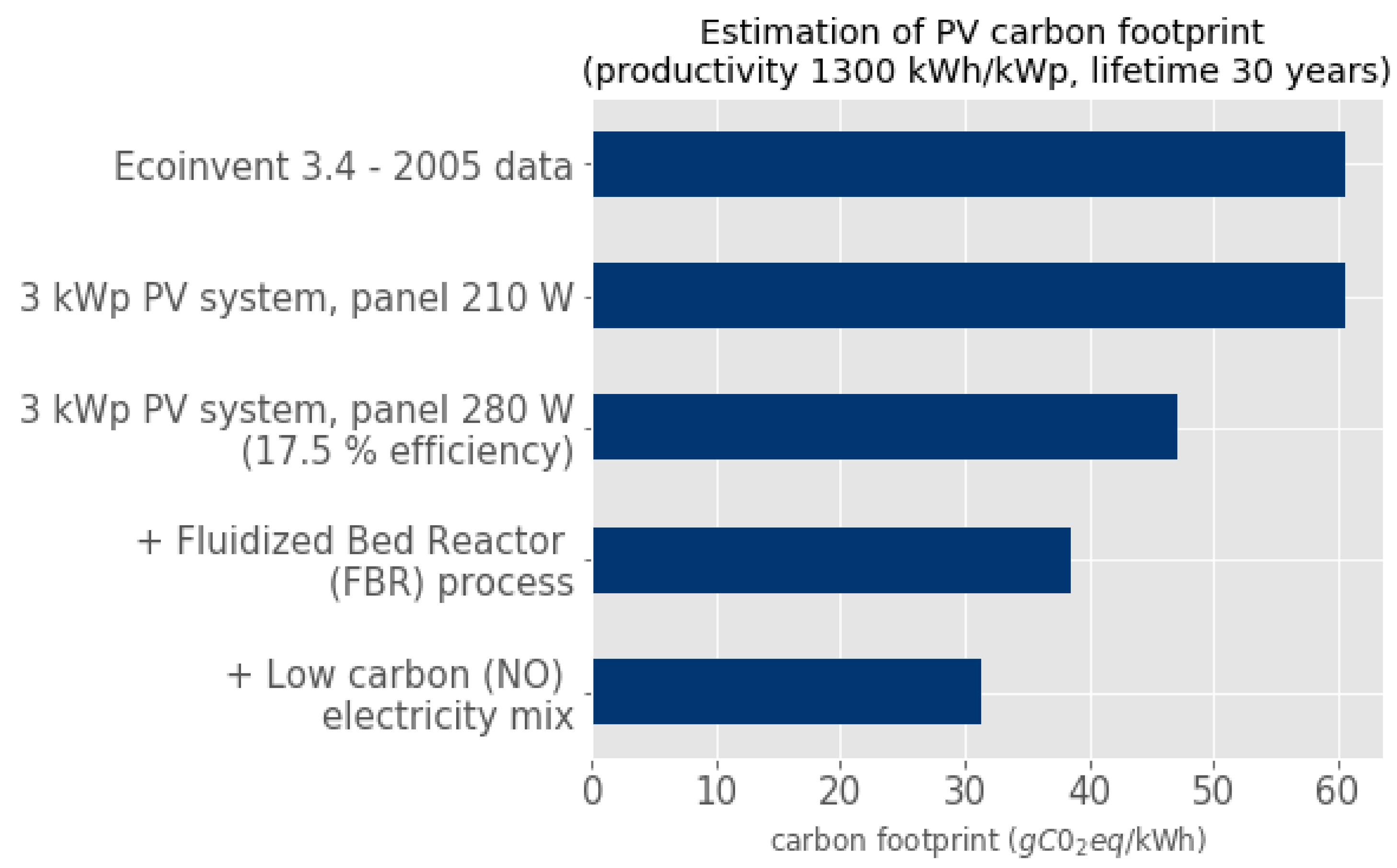
- A cradle-to-grave LCA approach is used to account for environmental impacts over system's life cycle stages monitored by more than 25 input variables.
- Life cycle inventories rely on ecoinvent 3.4 database while 4 impact categories were included: Global Warming Potential (GWP), cumulative energy demand (CED), respiratory effects inorganics, and freshwater ecotoxicity.
- The open-source LCA framework Brightway2, relying on Python language, is used for modeling.
- The case study focuses on 3 kWp PV installation roof-mounted with modules of multi-Si technology installed in South of Europe (1300 kWh/kWp) and manufactured with an average world electricity mix. Systems dating from 2005 and 2019 are compared.



Results & Discussions

- Per m² of cell, reductions of 40-50 % of GWP, CED, and respiratory effects and 21-22% of the freshwater ecotoxicity impact are justified by the reduced amount of material and electricity involved in the manufacturing phase for the cells adjusted by the parameterized model.
- Per kWh, the results of the original system (top bar) confirm the validity of the parameterized model (second bar) : 60-61 g-CO_2-eq/kWh. 3 scenarios are explored:
  - Higher panel power (280 W): 47 g-CO_2-eq/kWh (-21%)
  - Fluidized Bed Reactor (FBR) : 38 g-CO_2-eq/kWh (-36%)
  - Low carbon mix: 31-32 g-CO2-eq/kWh (-48%)





Conclusions & Perspectives

- Transparency and modularity of the parameterized model allow users to model and compare their systems in terms of their environmental performances in a time-effective manner by monitoring more than 25 parameters.
- 21-50% decrease in the impacts of the PV silicon cells / m² is associated with the latest technological advancements related to electricity amount and mix, wafer thickness, silver amount, cutting process, and kerf loss.
- Around half of carbon footprint / kWh is cut by integrating higher panel's power, FBR, and low-carbon electricity mix.
- The flexibility of this model allows simulations of different silicon-based PV systems, ranging from few kW to several MW, and other advances in the future. Further optimization may be integrated to address uncertainties.

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