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Environmental Impacts Associated With Photovoltaic Electricity From Crystalline Silicon And CdTe Modules Under Various Energy Supply Options

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The previous century's methods of generating our most useful form of energy, electricity, are recognized as unsustainable, due to either increasing CO_2 poisoning of the atmosphere or the increasing stockpile of radioactive waste with no safe storage. This partly explains why electricity production based on photovoltaic systems is increasing significantly. Life Cycle Assessment (LCA) methodology can be applied to evaluate the environmental impact of photovoltaic modules. LCA addresses potential environmental aspects and impacts throughout a product's life cycle, from acquisition of raw materials to production, use and end-of-life processing. In this study, global warming potential (GWP, Figure 1), primary cumulative energy demand (PCED, Figure 2) and energy payback time (EPBT, Table 1) of single-crystalline silicon (single-Si), multi-crystalline silicon (multi-Si) and cadmium telluride (CdTe) photovoltaic (PV) module production are estimated. Most LCA studies consider that the primary energy required to produce modules is mainly from non-renewable sources, following the standard convention that cells and modules are produced with the actual electricity mix from the manufacturing region. However, as the prices of PV systems are declining and facilities are growing rapidly, it is conceivable that they could be manufactured exclusively with electricity from previously produced PV modules manufactured from the same or similar facilities, which could lead to a new understanding of the environmental impacts of solar modules. All the processes to produce single-Si, multi-Si and CdTe modules are modelled using European energy mix (UCTE) as reference. The results are compared to the same processes using 100% photovoltaic electricity mix or 100% hard coal electricity.

Figure 1 shows greenhouse gas emissions using 100 year global warming potentials (GWP100) in gCO_2-eq/kwh considering various electricity mixes. When using 100% hard coal electricity or the European Energy mix, the highest share of the impacts is caused by the electricity mix used for the production of modules. The GWP100 of hard coal electricity is 2.65 times more important than the European energy mix. Manufacturing modules with 100% photovoltaic electricity allows reduction of the GWP caused by electricity by 90%. Figure 2 shows the PCED from non-renewable and renewable resources. Non-renewable energy resources are estimated to be reduced by 65% for single-Si, 53% for multi-Si and 35% for CdTe when using 100% photovoltaic electricity mix compared to the European energy mix during the production of modules. The total energy payback time decreases by 40% for single-Si, 36% for multi-Si and 24% for CdTe. (see Table 1).

The European energy mix and 100% hard coal electricity create the largest impact on the production of the modules, especially for crystalline silicon, due to the large electricity consumption during manufacture. This is how supplying solar electricity to the modules factory allows a large reduction in GWP for crystalline silicon. But, in this scenario, the choice of material (aluminium, glass, etc.) has more impact than the electricity mix. Using solar electricity to produce those materials would improve the results significantly. New LCA studies on solar modules on that basis might challenge, for example, previous findings about relative environmental impacts of different PV technologies.

Table I. EPBT of crystalline Silicon and CdTe modules under various energy supply

	electricity, hard coal, at power plant			**electricity, medium voltage, production UCTE, at grid**			**electricity, production mix photovoltaic, at plant**		
	Single-Si	*Multi-Si*	*CdTe*	*Single-Si*	*Multi-Si*	*CdTe*	*Single-Si*	*Multi-Si*	*CdTe*
Energy Payback Time (years)	1.656	1.033	0.359	1.578	0.993	0.350	0.945	0.639	0.267

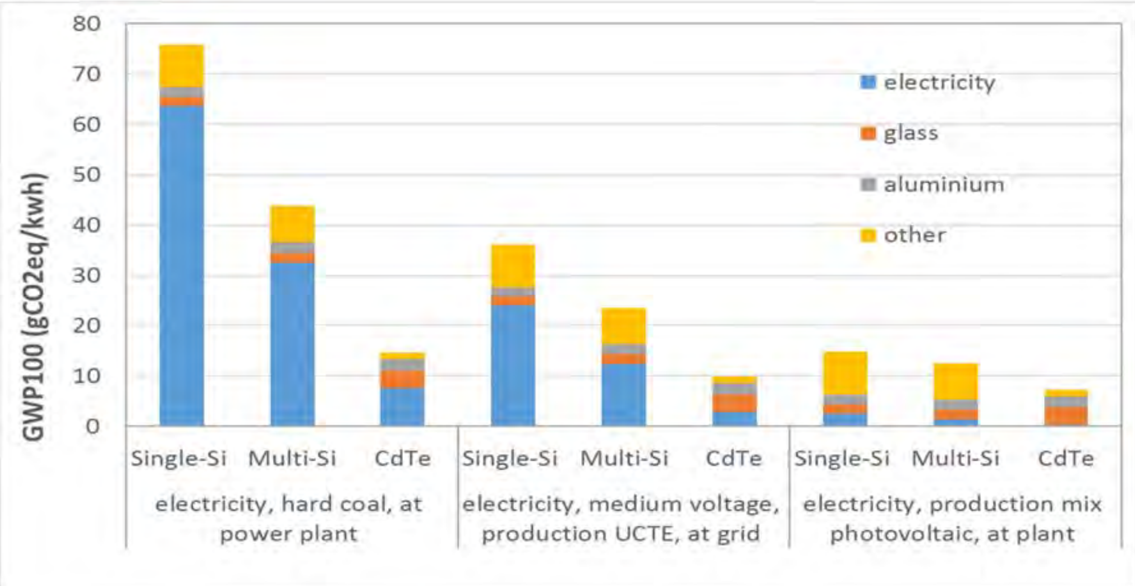

Figure 1. GWP100 of crystalline Silicon and CdTe modules under various energy supply

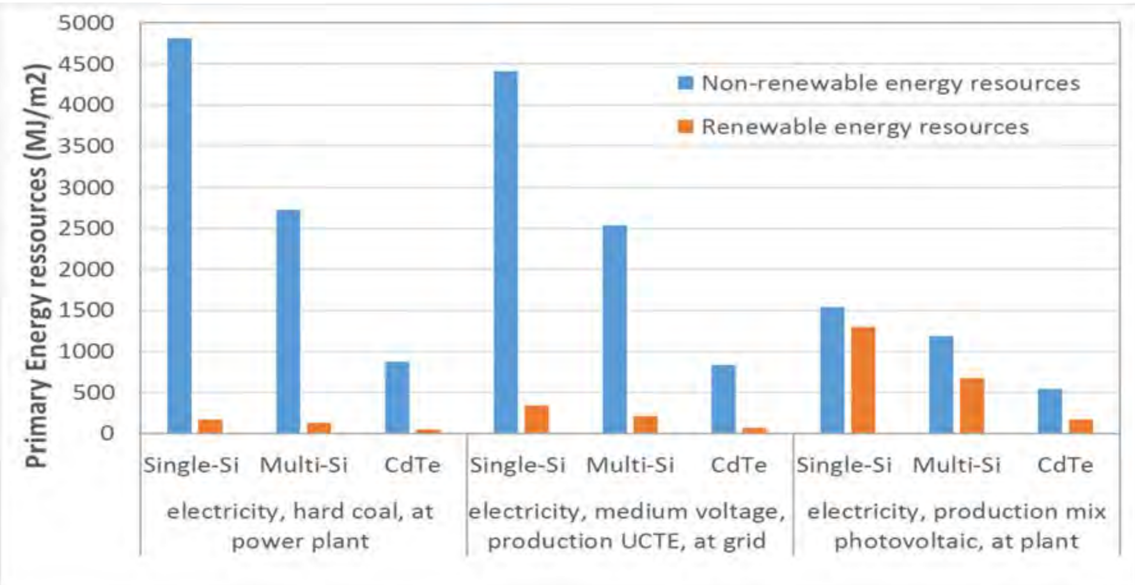

Figure 2. PCED of crystalline Silicon and Cdte modules under various energy suply