The Hidden Cost of Solar Energy

The current recycling capacity for solar panels can't cope with an influx of customers prematurely discarding their existing panels for cheaper, more efficient models.

Solar energy installations are booming across the globe. Solar power supply, which has already hit record highs in the European Union this year, will need to more than double per year in the next decade to meet the 2030 climate targets set by the European Commission. As of 2021, close to 12 gigawatts (GW) of photovoltaic (PV) energy are installed in France. This is projected to double by 2023 to match the Pluriannual Energy Programming Target, and then exceed 50 GWs by 2030 and surpass at least 100 GWs by 2050.

The rising popularity of solar energy can be tied to its falling costs. Just in the last decade, PV module prices have fallen by about 90 percent. This was thanks to economies of scale along the entire supply chain, following athe rapid growth in manufacturing capacity and several waves of manufacturing innovation driven by large Asian producers. There is also the impact of green-friendly regulations and incentives from governments worldwide as climate change becomes a serious threat.

A lifetime perspective

Amidst all the excitement about clean technologies, we might be overlooking the elephant in the room. These PV installations will have to be discarded once they are end of life (EOL). But what happens when they are not useful anymore? The average lifetime of a solar project is about 25-30 years. After this, the installed panels can be, in principle, disposed of (in a landfill), recycled, or refurbished and reused (Figure 1).

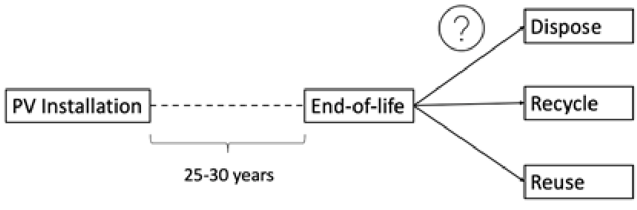

Figure 1. End-of-life options for solar PV installations

Burying old solar panels in landfills is not a sustainable long-term solution. The rapidly shrinking available landfill capacity makes it impossible to keep burying growing amounts of PV waste. It is also unwise, because the panels contain toxic substances, and valuable materials such as silver. Regulations may also ban the disposal of electronic waste as regular trash.

The alternative of reuse does not look viable either. Towards the end of its life, a solar panel that is still operational retains 70-80 percent of its original capacity due to the degradation of modules over time. Yet, considering the costs of dismantling, transportation and refurbishment of parts, it is often much cheaper to invest in a new, more efficient model. This leaves very little market (if any) for the resale of older panels.

Another option might be donating used panels for charitable purposes within the same market. However, the maintenance of older systems can be expensive due to increased upkeep requirements, a lack of spare parts and repair expertise. The older panels may also **not satisfy** current required safety regulations, making it altogether infeasible to keep them operational.

Finally, developing countries may be considered as **secondary markets** for these products. Unfortunately, the **cost of shipping** used solar panels remains perhaps too high to make this a viable option. Furthermore, this option pushes the burden of EOL treatment of these panels to regions of the world lacking environmental regulations that ensure the safe treatment of electronic waste, thus introducing serious health and environmental risks. Understandably, developing economies no longer want our trash.

The conventional wisdom scenario

The best solution for PVs at EOL is recycling, according to official industry and government sources. In fact, International Renewable Energy Agency (IRENA) and International Energy Agency (IEA) conducted a large-scale joint **study** of the solar PV end-of-life management problem in 2016. It painted the picture of a billion-dollar opportunity for the recovery of valuable materials and new employment creation through recycling.

According to these projections (Figure 2a), the world has between 25 to 30 years to prepare for the discarded modules. This is assumed to be enough time to build ample recycling capacity. Another assumption is that logistics costs will be negligible and that recycling technologies will have to be well developed enough to allow for efficient urban mining. This would make silver and copper recycling a potentially profitable activity.

By projecting waste from today's installations arriving decades in the future, this optimistic outlook leaves almost no gap between the projected revenues from the resale of recovered materials and the recycling costs of used panels. In fact, in countries such as France that enact **extended producer responsibility laws**, this optimistic projection is reflected in the tiny amount of **visible recycling fees** collected by or on behalf of producers at the time of installation.

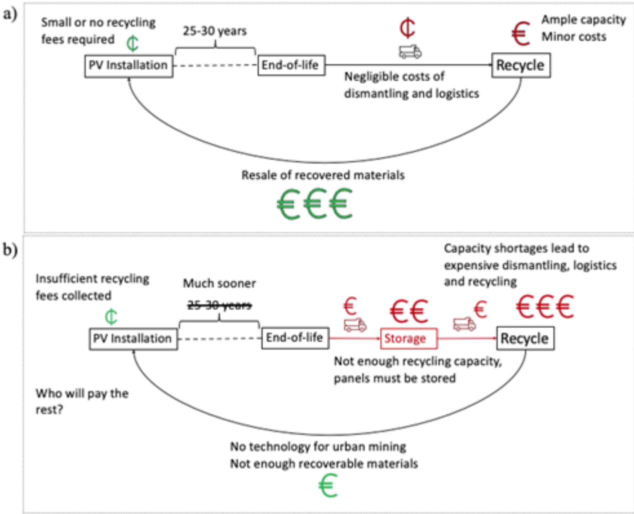

Figure 2. Recycling end-of-life scenarios 2a. Conventional wisdom suggesting 30-year lifecycles for solar panels 2b. Early replacement scenario with much shorter lifecycles for solar panels

A different, more cautious picture

There is a potentially much bigger threat looming on the horizon. The official projections discussed above are all based on the premise that customers keep their panels for the entirety of their 30-year lifecycles. However, in the last decade, total PV installation costs to end-users have fallen by more than 60 percent. Meanwhile, the energy conversion efficiency of the panels has continuously improved, by as much as 0.5 percent each year.

In essence, significantly cheaper and better models are introduced to market each year. This suggests that rational customers have the **economic incentive** to make the switch much earlier than the projected 30 years. As a result, there is a huge potential for widespread early replacement, purely driven by straight economics.

Assuming a fair number of people replace their panels early, a large flow of panel waste will arrive much sooner than anticipated. In fact, even in our conservative scenarios, we find that panel waste can reach a volume about **six times higher** than IRENA anticipated by 2030. Actual waste amounts introduced into the market can match the volume of new installations prior to 2030 (as opposed to 2050), and by 2035, four tonnes of used panels may need to be recycled for each tonne that is sold.

In this scenario (shown in Figure 2b), the status quo approach lacks the necessary recycling infrastructure. Since there is a time lag required to build recycling capacity, the returned panels will need to be thrown in a landfill or stored. Capacity shortages over time will lead to expensive dismantling, logistics and recycling, making the total recycling related cost much higher than anticipated. Finally, the technology for efficient urban mining is not ready yet. Not to mention that the available supply of silver and other valuable content in new designs is seriously declining.

In this case, it would not be surprising if the huge volume of used panels waiting for expensive end-of-life processing, combined with the lack of revenues from material recovery, as well as the inadequate visible recycling fees all lead to a massive shortage of funds to cover the recycling costs of solar panel waste. Furthermore, a number of PV producers may have left the market, leaving the remaining companies to carry the cost burden. Under this scenario, the levelised cost of solar energy could be up to four times higher than what is projected. This could even jeopardise the cost-competitiveness of solar technology.

This could result in a huge inflow, a bottleneck for processing and costs that are much higher than anticipated. All this sooner than expected and perhaps much sooner than we think (Figure 3).

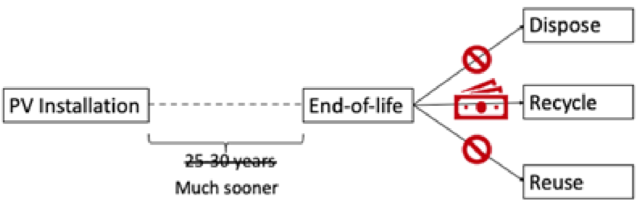

Figure 3. With early replacement, the recycling route becomes a huge bottleneck and is no-longer a cost-efficient end-of-life option

A call for immediate action

Considering that this darker scenario may come to pass, there is an urgent need to ensure large-scale and cost-competitive PV recycling infrastructure is built as quickly as possible. Furthermore, policy action is urgently required to guarantee that the EOL treatment costs connected to the burdens of disassembly, transportation, storage and recycling are fairly allocated to the actual producers of the installed equipment.

In complex systems such as these, there are time lags and dependencies between the activities at each stage of the supply chain. As such, it is crucial to take a system view. Only by looking at the big picture, can we anticipate and prepare for any potential bottlenecks and not miss any potential opportunities.

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