Scientific research enabling the development of the process of using recycled photovoltaic panels in the production of metal alloys.

The exponential growth of the photovoltaic (PV) installations is an important and desirable element in the global response to climate change. A typical PV module has a lifetime of 20-25 years. However, some will be damaged during production, transportation, handling or installation, and some will even stop functioning after sometime, while some would be discarded during testing called as factory reject modules. Increased use of PV panels for energy production would also lead to enormous volumes of PV waste that needs to be dealt with in an environmentally responsible manner. The growing amounts of PV panel waste presents new environmental and waste management challenges. Recovery of raw materials from the PV panels, or researching other applications of recycled PV modules could lead to establishment of new solar PV end-of-life industries. In-fact, solar PV recycling would be of paramount importance for the transition into a sustainable and economically viable renewables-based energy future. The importance of developing pathways for PV module recycling has been acknowledged and some recycling processes have been developed. However, the complexity of the recycling process is one of the prime reasons hindering their large-scale implementation and consequently limiting the growth of PV module recycling industry. Almost all research activities on module recycling has been focused on c-Si PV modules due to the fact that c-Si technology commands more than 95% of the solar PV industry. Almost all recycling efforts for crystalline silicon PV modules available in literature are directed towards recovering various materials such as external wiring, glass layer and the aluminium frames from waste c-Si PV panels to be used again in c-Si PV panels manufacturing. Several chemical means could be employed to recover precious metal (usually silver) and metal free silicon from the mixture which could be recycled. While chemical treatment to obtain pure silicon appears to be promising and attractive, it has several drawbacks. The process has to be tailored for different cell types and architectures. This makes the process extremely complex and prohibitively expensive. Additionally, the chemicals required for this process are highly hazardous and dangerous. To promote the recycling of the waste c-Si PV panels, it is important to research and develop safe and simple methods of recycling. Hence, **developing alternate pathways for recycling crystalline silicon PV modules that are simple and do not require complicated processes and hazardous chemicals** is an essential and promising research direction. For example, ferrosilicon (FeSi) could easily be obtained from discarded c-Si PV panels by melting the panels with scrap steel and could be used as deoxidizer, or Si carrier in manufacturing other metal alloys such as steel rebars and silicon steel used in electric motors. This could be the simplest method of recycling c-Si PV panels as it involves minimum processing steps and eliminates the use of toxic and hazardous chemicals.

The aim of this project is to develop simple recycling process for c-Si PV modules. Ferrosilicon made directly from PV modules, would contain some impurities such as silver, aluminium, phosphorus and boron in extremely small quantities. To understand the impact of impurities on the properties of the alloy, it will be imperative to understand the basic underlying scientific principles of a multi-component alloy system with trace impurities. Hence, the main **aim of the project will be to research the impact of the typical impurities from the solar panel on the properties of Fe-Si phase system**. Although the Fe-C-Si phase system has been investigated to some extent, the behavior of a multicomponent system involving minute quantities of Al, Ag, B and P is largely unknown. After understanding the behavior of the multi-component system, research would be done to further verify the findings by producing ferrosilicon alloys of various composition as governed by the kinetics and thermodynamics of the multicomponent phase system and characterizing their properties. The ferrosilicon would be produced with recycled materials obtained from PV modules and scrap steel, and hence would also include minor impurities. The ferrosilicon would be characterized and compared with the commercially available ferrosilicon using scientific methods. Further, the ferrosilicon produced from the recycled PV panels would be used for producing silicon steel, rebar steel and higher-grade ferrosilicon samples. These samples produced in the laboratory would be compared with the commercially available samples. This comparative study would help us establish and further improve the process. **Thus, the project will enable the scientific community to understand the behavior and impact of the trace-impurities on the properties of the alloys produced from end of life PV panels**. The knowledge could later be helpful to establish the feasibility of using materials recovered from recycled PV panels in the production of metal alloys used in day-to-day activities, while addressing the issue of recycling PV panel waste. The process, if established, is expected to recycle 100% of the PV panel waste.