In-situ resource utilization (ISRU) based power production system

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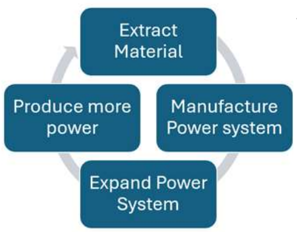
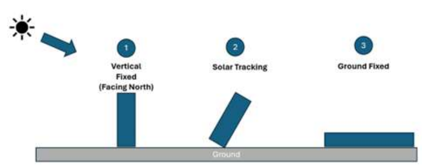
Introduction

Sustained human presence on the Moon and Mars requires scalable surface power systems. Current mission architectures depend heavily on hardware launched from Earth, limiting long-term infrastructure growth. In-situ resource utilization (ISRU) offers a pathway toward reducing this dependency by manufacturing power systems directly from local regolith resources. This study investigates whether photovoltaic (PV) solar panels and thermoelectric generators (TEGs) can be produced using lunar and Martian materials to create a positive-feedback "power bootstrapping" cycle, where locally generated energy supports energy demanding system such as ISRU processing and infrastructure expansion.



The analysis evaluates:

- Material extraction pathways
- Manufacturing feasibility
- Environmental performance
- Energy break-even time

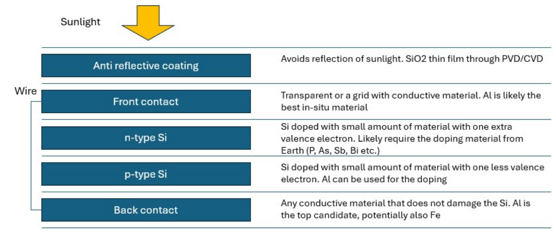


Three configurations for the simulation

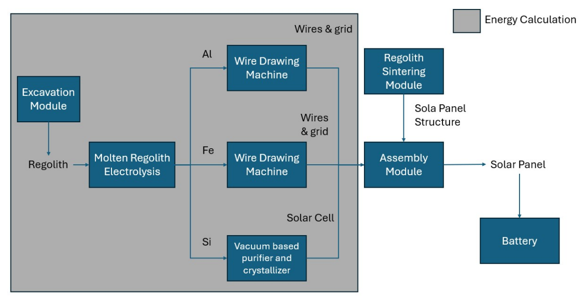
Tested the breakeven point based on three configuration. Solar tracking assumes the transportation of solar tracker and a motor to control the angle. The objective is to determine whether locally manufactured power systems can achieve net-positive energy return and support scalable and exponential extraterrestrial infrastructure growth for both Mars and the Moon mainly from the energy perspective. Assume we have initial 35kW power to support the ISRU production system.

REFERENCES
[1] Schreiner. Et al (2016) [2] Victoria. et al (2025) [3] Freundlich et al (2005) [4] Ellery et al (2022) [5] Garcia (2025) [6] Glaser et al (2018) [7] Girish and Aranya (2012) [8] Jaziri et al (2020)

Solar Panel



ISRU based solar panel structure



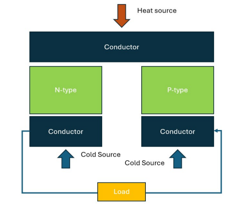
ISRU based solar panel production process

The PV system uses multicrystalline silicon solar cells with aluminum contacts and regolith-derived glass covers. The expected purity of the silicon is around 5N, which was included in the model. The wires and structure are built from aluminum and iron. Oxygen can be obtained as a byproduct through the process of extracting the metals and silicon, and it can be used for fuel or metabolic activities. Further study is required to determine the scalable energy distribution and storage system.

	Breakeven point (Earth days)			
	Moon	Mars (0N)	Mars (15N)	Mars (40N)
Solar Tracking	96	735	734	732
Vertical fixed	302	1037	1044	1068
Ground fixed	552	1087	1133	1360

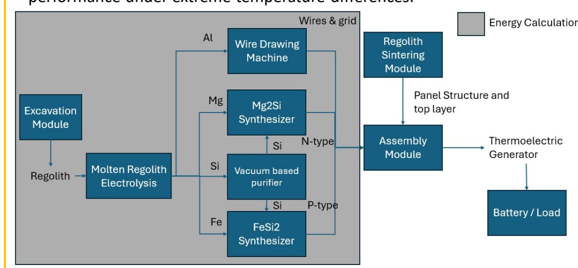
With three configurations, typical time to produce energy that was required to produce the solar panel is typically around 1~3 years including radiation and thermos degradation factor.

Thermoelectric Generator



ISRU based thermoelectric generator

The TEG node can be made with many different material selections. The material selection criteria for this project were based on the availability of materials on both Mars and the Moon, along with their relatively good performance under extreme temperature differences.



ISRU based thermoelectric generator production process

TEGs operate without moving parts and provide continuous baseline power independent of sunlight. We utilized the Lunar permanently shadowed regions and Martian subsurface for the cold source. Hot source would be mainly derived by the heat of solar illumination.

	Moon Breakeven point (day)			
Cold Source temp (K)	160	120	80	40
Solar Track	1103	893	765	688
Vertical Fixed	1771	1388	1155	990
Ground Fixed	121747	20080	3856	3995

Breakeven point (Earth day)				
Latitude	Config	145 K	175 K	198 K
10° N	Tracking	784	1136	1539
10° N	Vertical	795	1155	1569
10° N	Ground	812	1186	1616
25° N	Tracking	784	1136	1539
25° N	Vertical	811	1183	1611
25° N	Ground	850	1252	1720
55° N	Tracking	784	1136	1539
55° N	Vertical	811	1183	1611
55° N	Ground	1166	1816	2604

With three configurations and different assumption for cold source temperature, it has a longer breakeven point compared to PV.