2nd edition

Lunar market assessment

Building the Lunar economy: Sectorial forecasts and market opportunity

January 2026 | 2nd edition

Table of Contents

About this report

This publication was developed by PwC's Space Practice teams in France and Japan, building on our 2021 lunar market assessment. It integrates policy analysis, technological assessment, and economic evaluation to offer an updated perspective on the emerging and rapidly evolving lunar ecosystem, with a focus on infrastructure development. The report aims to provide a comprehensive analysis of the Moon's transition from a site of scientific exploration to a platform for sustained human presence and commercial activity, highlighting the emergence of a robust and interconnected lunar ecosystem.

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Foreword

Space exploration is entering a new era; one defined not only by scientific discovery but by the emergence of sustainable economic ecosystems beyond Earth. The Moon, once a distant scientific frontier, is emerging as a strategic platform for infrastructure development, resource utilization, and commercial activity. This report reflects PwC's commitment to supporting this transformation by providing a comprehensive analysis of the opportunities and challenges shaping the lunar economy. The aim is to deliver insights that help stakeholders—from governments to private enterprises—navigate this evolving landscape and unlock the full potential of lunar development.

Key messages

- The Moon is bound to transition from a site of scientific exploration to a strategic platform for sustained human presence and commercial activity.
- Regulatory clarity and international collaboration are critical not only to unlock private investment and ensure interoperability across lunar infrastructure, but also to deliver broader societal benefits—advancing technology, inspiring STEM careers, and fostering global cooperation.
- Technological breakthroughs—such as ISRU, 3D printing, and small nuclear reactors—are critical enablers for cost reduction and scalability.
- Lunar development is not an end in itself; it serves as a steppingstone for Mars exploration; it also delivers tangible benefits to Earth through technology transfer and industrial innovation.

PwC Space Practice Overview

PwC is one pf the largest professional services network in the world. With historical roots going back some 160 years, our network has over 370,000 professionals in more than 149 countries and 700 locations. The network also includes Strategy&, a strategy consulting firm dating back to the early days of management consulting, with a strong heritage in Aerospace and Defence.

PwC has a dedicated Space Practice with a global footprint and a core strategy and transformation-oriented team distributed across the globe. Unique among large professional services firms, our Space Practice combines dedicated and focused space expertise with a significant reach into the broader downstream.

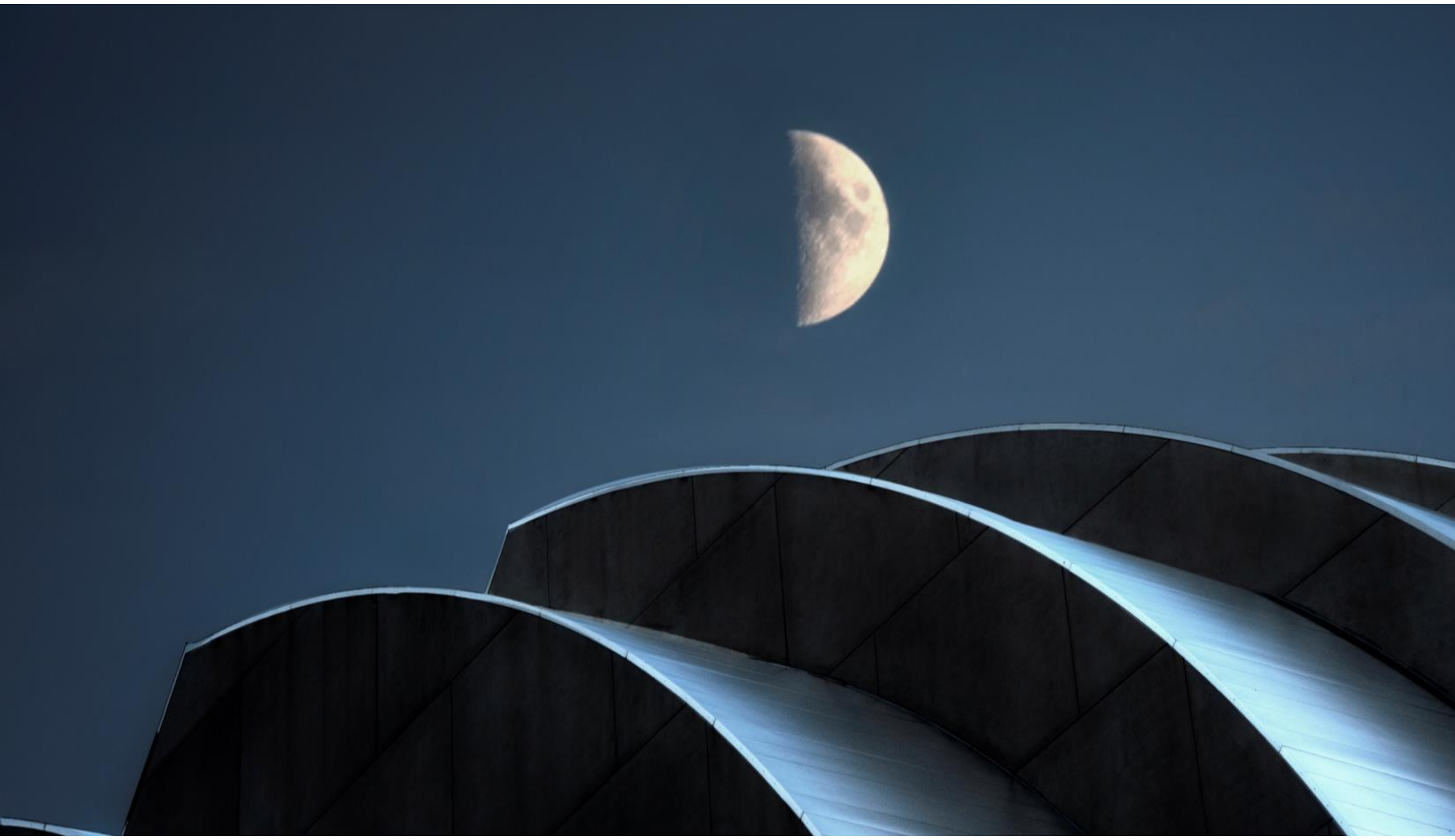
The scope of the core global team encompasses strategy, policy, economic studies, governance, technology, people and organization, and regulatory analysis, for a tailored support accounting for all the specificities of the space sector.

Our core space team acts as an enabler across the broader space practice, which encompasses lines of services like Audit and Assurance, Tax, Technology and Operations, in a seamless fashion.

Our unique perspectives and engagements focus on offering our traditional services to Space companies (i.e., audit, tax, business transformation, and market insights), as well as offering space-tailored services to all companies outside of the traditional A&D and Space sectors that focus on "unlocking the value of space."

01 Introduction

Building the Lunar economy: Sectorial forecasts and market opportunity



The Moon is rapidly emerging as a potential focal point for future global economic activity in space, marking a significant transition from purely scientific missions to ambitions centered on sustained human and commercial presence. Over the past decade, accelerated investments by space agencies and private industry have transformed the lunar landscape, positioning the Moon as a critical platform for future infrastructure, resource utilization, and business opportunities.

Since the previous proposed assessment of the lunar market in 2021[1], which explored transportation, data services, and resource extraction, the sector has continued to mature. Today, lunar initiatives are marked by growing international competition and notable technological advances. Programs such as NASA's Artemis, China's International Lunar Research Station, and new commitments from the ESA and JAXA underscore a global push towards establishing long-term lunar infrastructure.

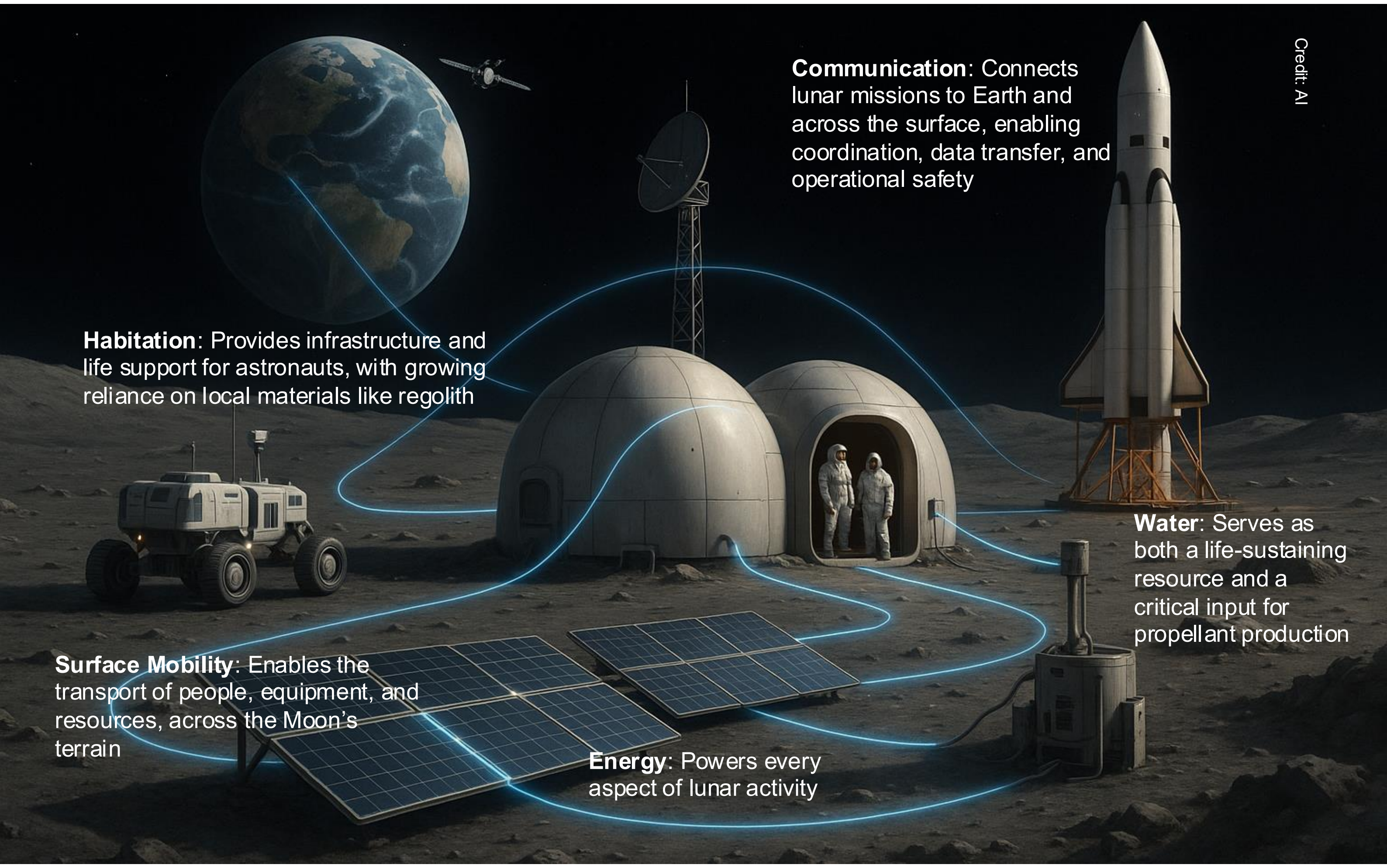
However, the pace and scope of these initiatives are often shaped by the stability of funding and political commitment. For instance, NASA's Artemis program has faced periods of budgetary uncertainty, illustrating how fragile financial support can impact timelines and ambitions. Alongside these efforts, emerging space nations and an increasing number of private ventures are developing landers, rovers, telecommunications, power systems, and resource extraction technologies for the lunar surface. While there is renewed attention on the Moon, the development of a lunar economy remain at an early stage, still largely driven by government investments and supported by industrial actors preparing for potential future commercial opportunities. Although public funding currently accounts for most lunar expenditures, there are indications of a gradual trajectory toward greater private sector involvement. New business models are beginning to emerge around infrastructure provision, in-situ resource utilization, and surface services, which could lay the groundwork for future commercial markets on the Moon.

The philosophy underpinning the future lunar economy represents a departure from the traditional mission-based approach. Rather than focusing on isolated, time-limited expeditions, the emphasis is shifting toward the development of a comprehensive and sustainable ecosystem. This ecosystem will be the key enabler of long-term presence and broader ambitions.

This report builds on recent sectoral developments and examines the economic potential of lunar infrastructure from 2026 to 2050. It assesses the overall prospects for economic activity driven by the emergence of this ecosystem. The pace of this activity will be shaped by three key variables: the number of missions, the projected crew presence, and the infrastructure required to support them. In addition to estimating potential revenues, the report evaluates the scale of investment needed to develop, launch, and operate the necessary capabilities. However, it is noteworthy that this report does not constitute a cost-benefit or profitability analysis. Revenues and investments are largely decoupled across market segments. Importantly, the revenue projections exclude any income from asset construction and manufacturing, as these activities are accounted for exclusively within the investment component.

As lunar activity accelerates, understanding the scale, timing, and structure of emerging market opportunities will be critical for stakeholders aiming to participate in the next phase of lunar development.

02 Market and scenario description



Research scope

This analysis of market opportunities for lunar surface activities over the 2026–2050 period is based on a scenario-driven forecasting approach, grounded in publicly available data, planned mission architectures, and expert interviews. The scenarios have been constructed by aggregating concrete plans and official statements from the leading lunar space actors: the United States (NASA's Artemis and the associated commercial partnerships), China (Chang'e program and the prospective crewed landings), Japan (JAXA's partnerships and technology demonstrators and testing), India (ISRO's ambitions), Russia (Luna-Glob program), and the European Union (ESA-led initiatives and participation in international collaborations). This approach establishes a credible baseline for lunar activities through the early 2030s and employs extrapolative logic for subsequent decades, with clear justifications for all key assumptions.

The quantification of economic opportunities and required investments – whether by public institutions (as part of overall demand) or by private companies (as capital needed to capture future revenues) – is directly linked to the activities envisioned within the emerging lunar ecosystem. While near-term developments can be forecasted with relative confidence, projecting the evolution over a 20-year horizon remains inherently more uncertain. To structure the analysis, five core domains have been properly defined—surface mobility, communication, habitation, energy, and water—each representing a foundational pillar of the lunar economy.

Within each domain, the analysis identifies investment needs based on key technological inflection points, encompassing R&D, development, manufacturing, transportation, and operational costs. These investments are currently undertaken primarily by public institutions—such as NASA, ESA, and other national space agencies—which drive the initial phases of lunar infrastructure and technology development. However, as the lunar economy evolves, private companies are expected to play an increasingly significant role, investing capital to unlock future revenue streams as commercial opportunities emerge. In parallel, the analysis estimates potential revenue streams, defined as income generated from infrastructure sales and service provision by economic operators within the ecosystem.

It is important to note that this report does not aim to provide a direct cost-benefit comparison. A comprehensive cost-benefit analysis (CBA) would require a full end-to-end assessment of the lunar value chain, extending beyond infrastructure deployment and operations. Conversely, a company evaluating the profitability of a specific lunar business case would likely focus on a narrower scope—covering only a subset of the investments and revenues discussed here. This report focuses exclusively on lunar infrastructure; while it does not directly analyze downstream business models, the infrastructure described here will serve as the foundation for additional businesses—such as those referenced in the revenue section—and for a wide range of future use cases that may emerge as the lunar ecosystem develops. As such, the figures presented should be viewed as macro-level indicators, offering a sense of the scale and complexity of the opportunities and challenges associated with lunar development.

Lunar visitors' scenarios

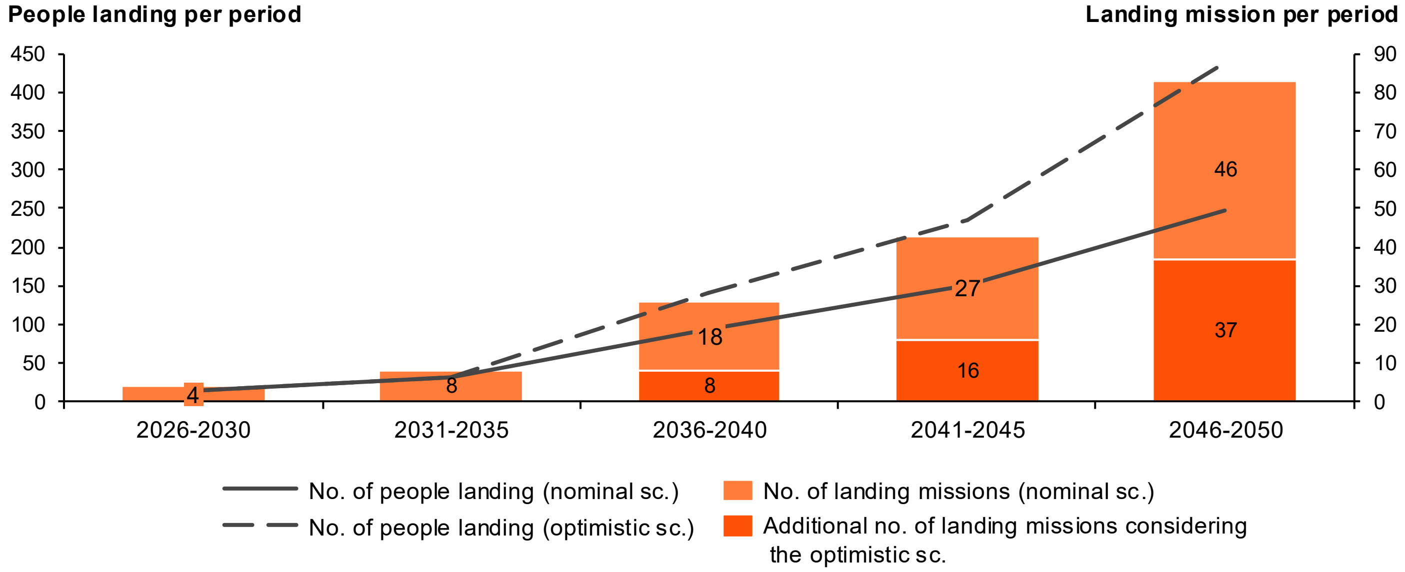
The number of human visitors and the frequency of missions are used as the primary demand driver for the quantification, with market sizing reflecting both direct (e.g., sales of mobility systems) and indirect (e.g., enabling infrastructure) costs and revenue opportunities. The analysis further considers the evolving mix of government and commercial participation, regulatory frameworks, and technological readiness as variables that will shape the market trajectory. To underpin the market sizing, two distinct scenarios – nominal and optimistic – are envisaged for lunar surface visitors and missions over five consecutive five-year periods.

Each period represents a key phase in the evolution of lunar activity, reflecting anticipated increases in mission frequency, diversity of participants, and commercial involvement. For each period, the total number of people landing on the Moon and the number of dedicated landing missions were estimated by analyzing transportation capacity per mission and known government objectives.

A key distinction is made between governmental and commercial visitor streams. While government-led missions dominate early activity, commercial passenger traffic is expected to emerge only from 2036 onward in both scenarios, reflecting the anticipated resolution of technical and regulatory challenges. From 2041 onward, a balanced model is assumed, with at least one government-sponsored astronaut accompanying each commercial crew—ensuring regulatory oversight and risk-sharing.

Another important factor is the assumed length of stay for the individuals involved. This length of stay on the surface starts from a few days and increases to 45 days on the surface in the later period for governmental astronauts, and up to 3 months in the optimistic scenario. For commercial actors, a shorter stay on the surface is foreseen, from a few days initially and up to 2 weeks in the later periods of the forecast.

Overall, while the nominal scenario reflects a growth pace in line with current plans followed by an incremental acceleration, the optimistic scenario assumes several positive accelerators: sooner commercial market entry, greater international collaboration, more rapid infrastructure deployment, and policy environments that actively enable private sector participation. These assumptions yield a substantially higher number of both missions and lunar visitors, especially in the final decade.



03 Markets assessment

In this report, we analyze the size of the lunar market by defining two cases: nominal and optimistic scenarios. Both have been benchmarked through government and commercial plans currently available but while the former assumes that various types of lunar infrastructure will be introduced on a standard timeline, the latter reflects a more forward-leaning assumption in which infrastructure is introduced earlier than in the nominal scenario.

It is important to note that in this report, investment refers to the total amount of funding required to develop infrastructure on the lunar surface, while revenue refers to the sales generated by business activities that emerge once such infrastructure is in place.

For each market segment, investment costs consist of three components: manufacturing costs, transportation costs, and operational costs. Manufacturing costs include research and development expenditures associated with the relevant technologies and are assumed to be incurred during the initial introduction phase.

Lunar surface mobility market

Achieving sustainable activities on the Moon requires reliable mobility systems that enable transportation, logistics, and operational support. Among these, rovers are expected to play a central role, supporting a wide range of functions (e.g., exploration, construction, communications, and logistics), serving as a core platform that contributes to every phase of infrastructure development.

Assumptions and scope

Rover Classification and Deployment Outlook

Lunar rovers can be broadly classified into three categories—small, medium, and large—each defined by their scale, functions, and role in future lunar activities. In evaluating the lunar surface mobility market, the scale of rover deployments serves as a decisive driver shaping both investment costs and revenue potential. Accordingly, the following sections present the definitions of each rover category and outline their respective deployment projections.

Small Rovers (unpressurized)
Lightweight unpressurized vehicles, with a mass of a few kilograms, those vehicles are designed for tasks such as exploration, environmental monitoring, and communications relay. Their compact size enables the simultaneous deployment of multiple units, making them suitable for distributed observation and data collection. Since the mid-2020s, they have been introduced by multiple nations and private companies, serving as the primary platforms for early lunar activities. Numerous commercial missions are planned, led by companies such as Astrobotic, ispace and Dymon. Owing to their low cost and lightweight design, they are suitable for a wide range of applications including sensor deployment and communications relay. By the 2040s, deployment is expected to reach several dozen to several hundred units, making small rovers the most widely adopted category.

Medium rovers (unpressurized)
Generally weighing several tens to hundred kilograms, these multipurpose unpressurized platforms can support sample collection, cargo transport, communications relay, and energy supply. Equipped with long-range mobility and autonomous driving capabilities, they act as a critical link between exploration activities and base construction. Medium rovers are expected to expand their role from early scientific exploration to supporting future construction, in line with the overall progress of lunar activities. Initial deployment is expected from the late 2020s, exemplified by the LUPEX mission, a joint initiative between JAXA and ISRO to investigate lunar water resources, with Japan responsible for rover development[2], and NASA's Lunar Terrain Vehicle (LTV), planned for first use in Artemis V in 2029[3]. From the 2030s, broader international participation and private sector involvement are expected to accelerate deployment, reaching several dozen units per phase across the 2030s and 2040.

Large rovers (pressurized)
High-capacity platforms with a mass ranging from several tons to double-digit tons, designed to support crewed exploration and long-duration surface stays.

Featuring a pressurized cabin that provides living and working space, they function as mobile bases for heavy-duty operations and construction. Large rovers are equipped with pressurized environments, power systems, and autonomous driving capabilities, enabling them to support construction and the installation of large-scale equipment. The most advanced project to date is the Lunar Cruiser, jointly developed by Toyota Motor Corporation and JAXA, which NASA also plans to integrate into the Artemis program with deployment targeted for the early 2030s. Comparable projects have not been confirmed in other countries, but are likely to follow in the late 2030s and 2040s. While initial deployment in the 2030s will be limited, the pace of introduction is expected to accelerate toward the late 2040s, driven by technological maturity and rising operational demand.

Overall, rover deployment is expected to progress in stages—small to medium to large—reflecting technology maturity, diversification of development actors, and infrastructure expansion, with adoption expanding significantly by the 2040s.

Demand Assumptions

For small and medium rovers, based on recent contracts announced by NASA for the Artemis missions, the revenues for unpressurized space mobility are estimated based on the provision of rover services (moon-rover-as-a-service)[4]. Instead of attributing a revenue tied to the purchase and operation of a lunar vehicle, which could be calculated as a cost-plus contract, it is assumed that there is a fee for the provision of lunar rover services for a given year, related to the expected NASA demand, and this number is scaled up in proportion to the expected institutional and commercial demand forecasted in our model.

The institutional demand is estimated in proportion to the number of people and missions simultaneously staying on the moon during a given time period. The commercial demand is estimated in proportion to the institutional demand.

The current institutional demand projected by NASA, as per the LTV services contract, consists of a $4.6B contract over 10-15 years. This assumes that NASA will be using 75% of the available services capacity, which is to decrease to 50% after some time[4].

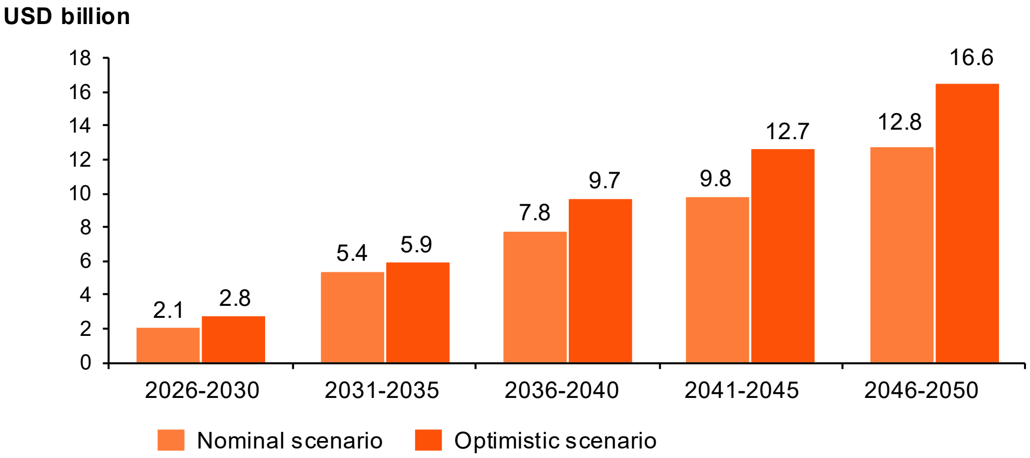
It is assumed that in the first 5 years, NASA will be spending $552M per year on LTV services, and after that, $368M, and that in the following years, this value will scale proportionally to the number of people staying on the lunar base.

On the commercial side, based on the Lunar Terrain Vehicle request for proposal, it is expected that the commercial spending on lunar mobility services is one third of that of institutions[4], and from then on, it is on par with that of institutions.

Looking at large rovers, demand for these is expected to be lower than that unpressurized rovers, as its main function is to be deployed on missions where there is a need for an extended range and/or duration. On the other hand, it is expected that the service is more expensive when considering an “equivalent” usage. Given that no commercial initiatives exist at this point, with Jaxa leading the development of the Lunar Cruiser, it is assumed that a cost-plus fee is implemented, at an average value of 8%, according to industry’s practices.

Market Assessment

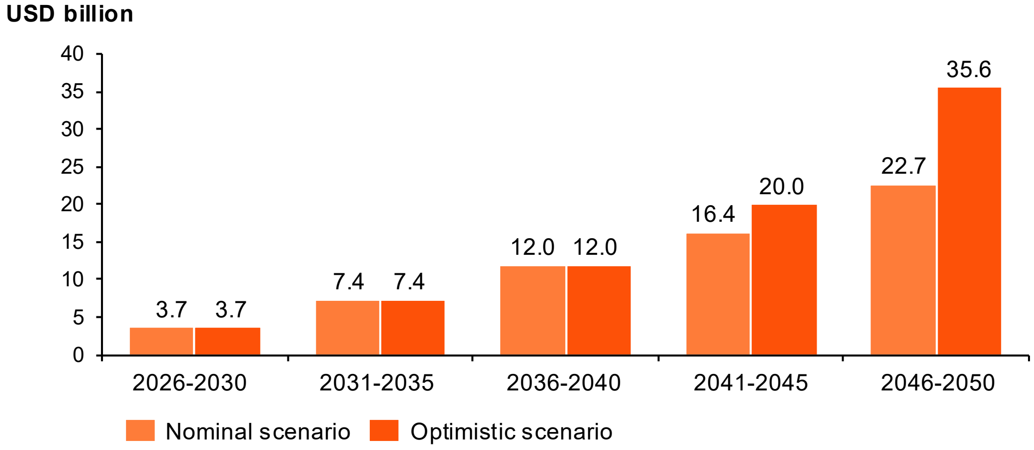
Investments assessment



Manufacturing costs are the primary driver of the needs for investment, expanding in line with increasing rover deployments and rising sharply in later phases as large rovers are introduced. Transportation costs also continue to grow in absolute terms; although the total expenditures are driven by the expansion in rover numbers while the market witness's efficiency improvements in per-kilogram transport costs. Operating costs remain smaller in scale compared to manufacturing and transportation, but they also increase steadily in later phases, reflecting the growing need for maintenance and operational support as rover deployments expand.

As a result, the investments in the mobility market are projected to expand progressively across phases from 2026 to 2050, reaching a cumulative total of approximately $37.9B in the nominal scenario (and up to around $47.7B in the optimistic scenario). The period from 2046 to 2050 is expected to represent the peak of investment, marking the phase in which the lunar mobility market reaches its highest level of activity. This expansion is driven by the cumulative growth of small and medium rovers, introduced since the 2020s and reaching their highest levels by the 2040s. It is further reinforced by the increasing deployment of large rovers—initially introduced in early operational use in the mid-2030s and subsequently scaled up in line with the growth of lunar visitors in the 2040s.

Revenue assessment



As described in the above assumptions, revenues for unpressurized vehicles scale with the moon occupancy, and hence follow the accelerating growth pace assumed for surface missions and number of people. Revenues for larger pressurized rovers are proportional to the investment's projections described above, as these large vehicles are more likely to fall under an institutional scope. As a result, in the nominal scenario, revenues scale from $3.68B in the 2025-2030 period to $22.7B in the 2046-2050 period. This translated to a cumulative result of approximately $62.2B.

In the optimistic scenario, revenues start at the same value of the nominal scenario, and peak at $35.6B in the 2046-2050 period, which is equivalent cumulative reaching $78.7B over the total period.

Credit: NASA

Communication market

The realization of sustained activities on the lunar surface requires the establishment of reliable communication infrastructure. This consists in a multilayered system comprising local networks within and between surface modules, relays via lunar orbital satellites and direct Earth–lunar links, supporting together a wide range of needs from daily monitoring of infrastructures to telemetry links, data transfers for mission control or communications for astronauts.

Assumptions and scope

Structure of Lunar Communication Demand

Communication demand on the lunar surface can be categorized by location and end points:

Inter-habitat communications
Between habitat modules and involving the routine sharing, synchronization, and backup transmission of scientific data, environmental monitoring information, and operational logs.

Module–rover communications
Between rovers and habitat modules, supporting the exchange of images, videos, environmental measurements, and navigation data. The communication volume varies significantly depending on rover missions.

Surface–lunar relay satellite communications
From the lunar surface to relay satellites, transmitting environmental and operational data; and from relay satellites to the surface, delivering operational support data.

Lunar relay satellite–Earth communication
Between relay satellites in lunar orbit and Earth ground stations, relaying environmental data and operational logs from the lunar surface, while transmitting operational commands, software updates, and analytical results from Earth to the Moon.

Direct-to-Earth communications
Direct links between near-side lunar bases and Earth, without the use of relay satellites. Lunar bases transmit environmental data and operational logs, while Earth provides operational commands and updates.

Key components of lunar communication infrastructure

To meet communication demand on the lunar surface, the infrastructure is composed of the following key elements:

01 **Lunar relay satellites**
Serving as the backbone of lunar–Earth communications, these satellites provide redundancy and reliability through deployment in multiple units. Future enhancements are expected to include Ka-band and optical communication capabilities, enabling higher-capacity data transmission.

02 **Dish antennas**
Envisioned as primary ground-based facilities at lunar outposts, supporting both direct communications with Earth and communications with lunar relay satellites. High-gain antennas are assumed to ensure the stability and efficiency required for long-distance communications.

03 **Base stations**
Supporting local communications within and around lunar bases, through Wi-Fi, wired networks, or cellular systems. They are expected to serve diverse applications ranging from daily crew use to rover control and video transmission, thereby functioning as critical local communication infrastructure.

04 **Data centers**
Facilities for storing and processing data collected on the lunar surface. Initially introduced with a focus on storage, they are expected to evolve to incorporate edge computing capabilities, reducing communication loads and enabling real-time data analysis.

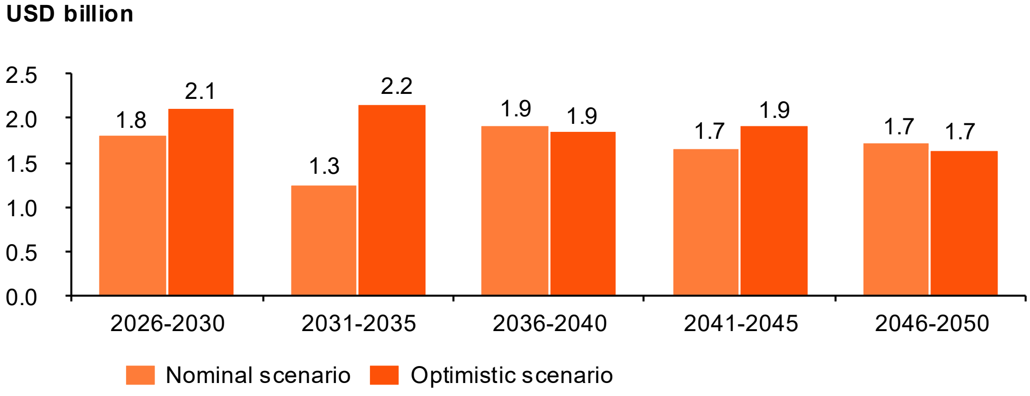
Pricing Assumptions

For the communications market, revenue is broken down into 4 streams, each one with different assumptions:

- **Satellite communication**: To calculate this, a proxy with the contract attributed by NASA to Intuitive Machines for the expansion of data transmission services for lunar and deep space missions, which consists of a $4.82B contract for the provision of communication and navigation services over 10 years[5]. This is scaled for the increasing lunar population.
- **Dish antenna**: A proxy with Earth's 4G data is used, considering a worst-case scenario. Currently, the most expensive mobile data in the world is in Zimbabwe, at $44/GB[6]. The data volume considered for this calculation is that of the inter-module data and module-rover data traffic.
- **Base station**: Here again an Earth worst case scenario proxy is used, considering that in Cuba, the average contract for monthly internet stands at $211 per month[6]. The data volume considered is the intra-module traffic.
- **Data center**: The worst-case Earth proxy selected was a South American company with a data center volume figure of $0.16/GB[7].

Market Assessment

Investments assessment



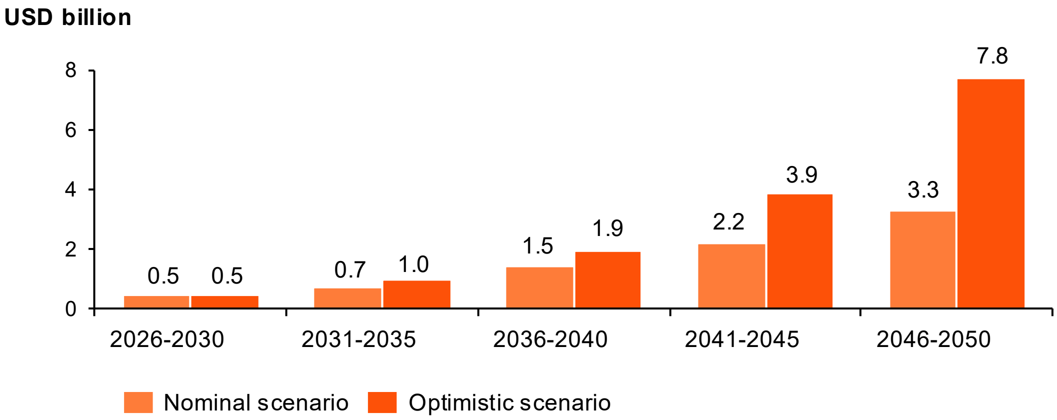
The cumulative investment in lunar communication infrastructure from 2026 to 2050 is estimated at approximately $8.4B under the nominal scenario and $9.7B under the optimistic scenario. Overall, a steady level of investment is expected from the early stages after 2026, with the focus of spending gradually shifting in line with the progress of infrastructure development.

In the initial deployment phase (2026–2030), investment is primarily directed toward the launch and deployment of lunar relay satellites, which form the backbone of communications between the Moon and Earth. During this stage, transportation, manufacturing, and research and development costs represent a major portion of total investment, driving the overall level upward. Under the nominal scenario, the temporary dip in 2031–2035 reflects both declining transportation cost per kilogram and the front-loading of R&D for lunar relay satellite development in 2026–2030, after which investment naturally moderates.

Entering the 2030s, investment expands to include the installation of lunar surface communication infrastructure, such as ground-based dish antennas and communication stations, as the number of lunar visitors increases. In parallel, the introduction of lunar data centers begins to meet the growing demand for data transmission and processing. In the nominal scenario, data center deployment starts between 2036 and 2040, whereas in the optimistic scenario, it begins earlier—between 2031 and 2035—making this earlier rollout one of the main factors behind higher investment levels in the optimistic case.

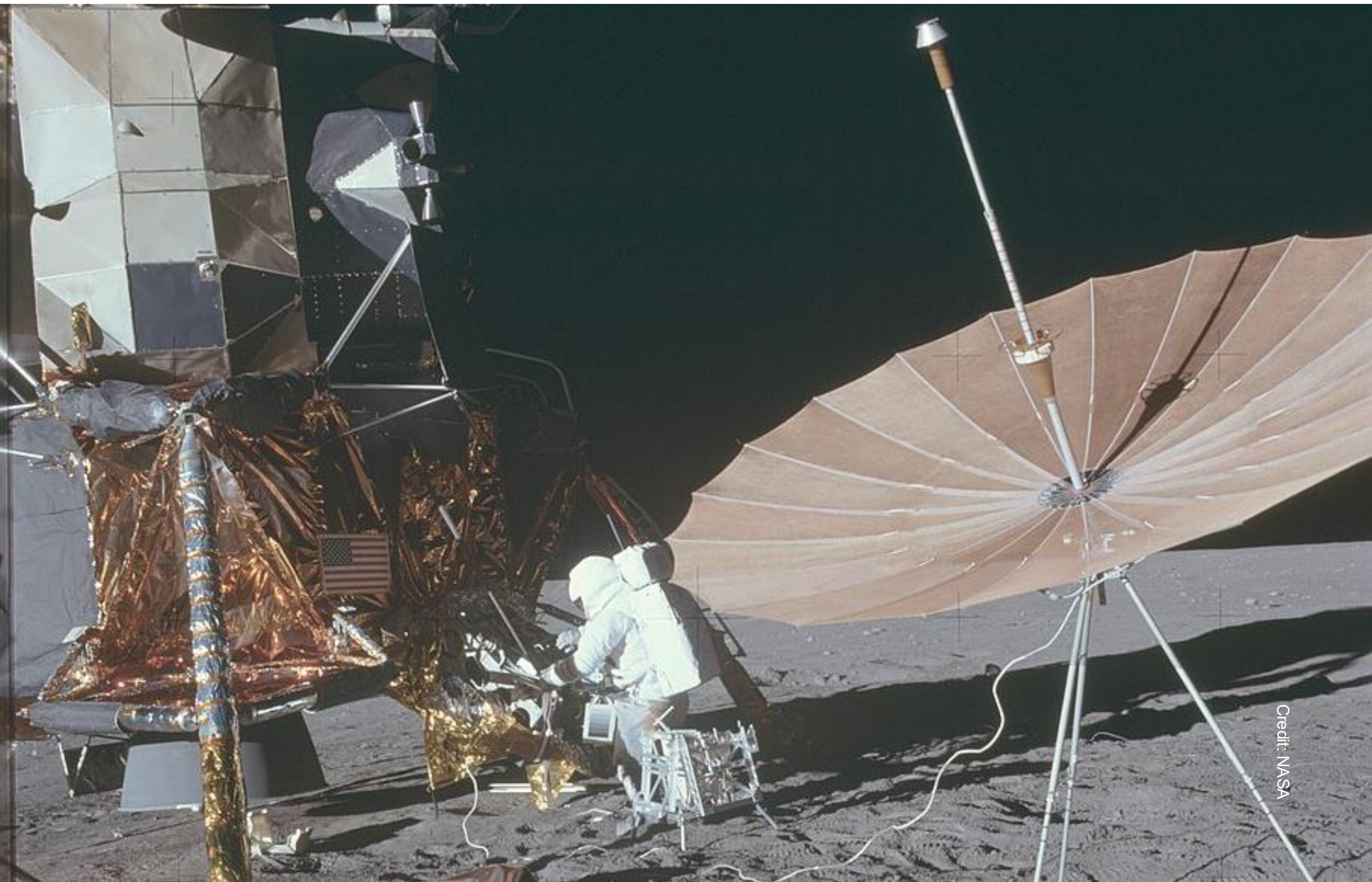
From 2040 onward, the increasing number of habitation modules and communication users is expected to drive the continued expansion and renewal of lunar antennas and stations. In addition, lunar relay satellites will continue to be replaced and supplemented by both government and private operators, maintaining a stable level of investment. Over time, the focus of investment will gradually shift from new construction and deployment toward operations and maintenance activities.

Revenue Assessment



The revenue in a nominal scenario progresses from $0.48B in 2026-2030 to $3.3B in 2046-2050 period, which leads to a cumulative of $8.1B. The optimistic scenario has higher returns, with the evolution of $0.48B in the first period, culminating at $7.8B.

The main driver of revenue is the part related to the space assets, as it is also the main driver of investment. The optimistic estimate is much higher, as we assumed that the satellite returns scale with the number of occupants on the Moon.


Credit: NASA

Habitation market

Lunar habitation is a core component of the Moon's economic future, supporting a sustainable human presence by hosting and protecting astronauts, equipment, and infrastructure. Multiple stakeholders are actively developing concepts and architectures to deliver resilient, functional, and comfortable habitats for future lunar missions. These habitats must balance the needs of human living spaces with the technical requirements of scientific installations and operational infrastructure, as seen in current space station designs.

Assumptions and scope

The market for lunar habitation modules is expected to emerge in the early 2030s. During the initial Artemis missions, NASA plans to use the lunar lander as a temporary living space, followed by the deployment of the permanent Foundation Surface Habitat. In parallel, several agencies and companies are exploring habitation module concepts. For instance:

- Spartan Space is developing the inflatable habitat module EuroHab[8].
- Skidmore, Owings & Merrill is collaborating with ESA on the Moon Village concept[9].
- The Aerospace Corporation has patented a lunar habitat concept called Regishell[10].

All these concepts are intended for deployment post-2030, with potential revenues expected to begin thereafter.

The link between investment and revenue is direct: early institutional investments enable the deployment of infrastructure, which in turn creates the foundation for commercial services and revenue generation. As private sector participation grows, investments increasingly target scalable, cost-effective solutions that unlock new revenue streams.

Supply methods for Lunar habitation modules

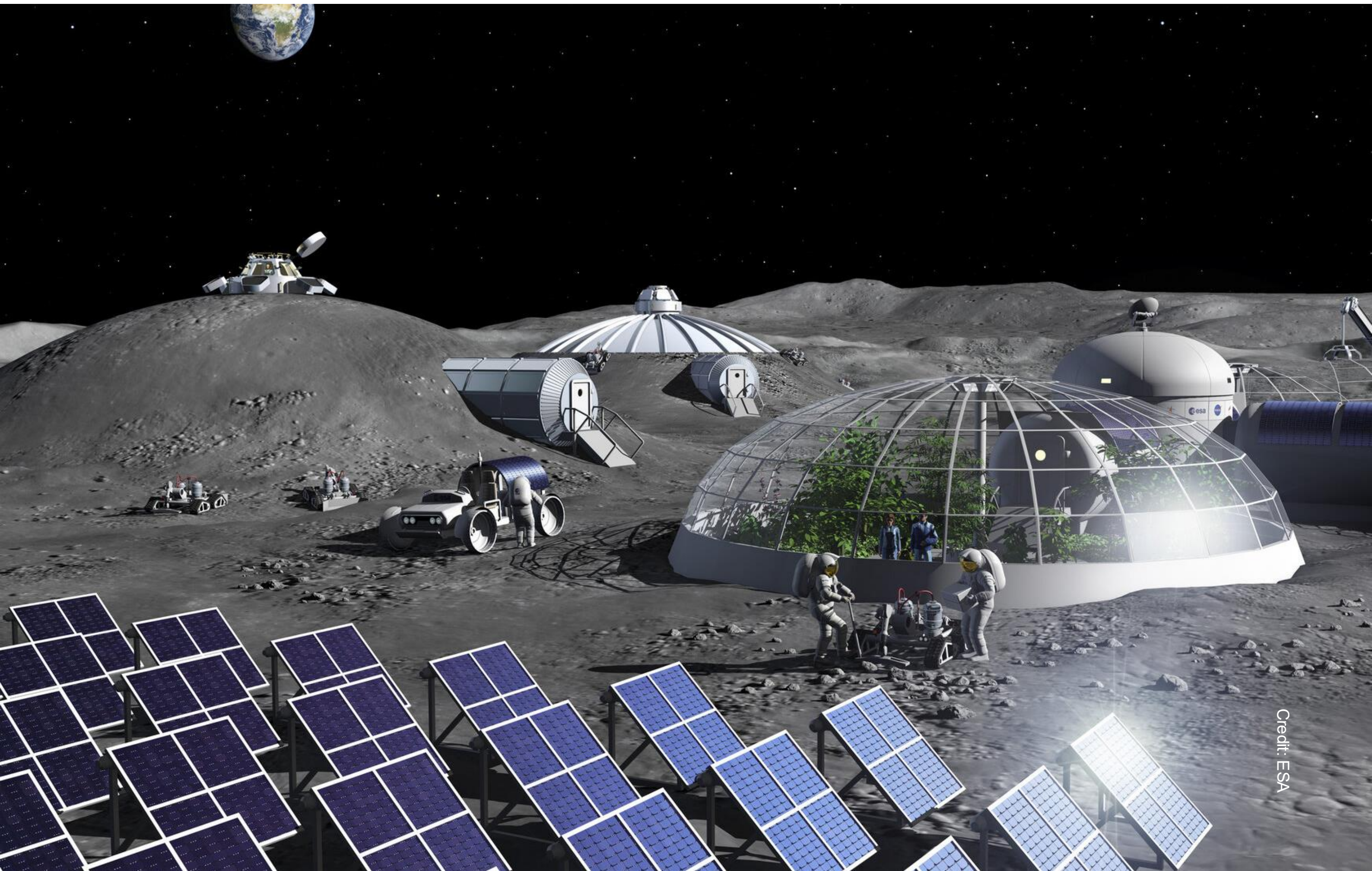
The supply of lunar habitation modules is divided into two primary approaches:

- Earth-transported modules: These modules are manufactured on Earth and delivered to the lunar surface, ensuring high production standards and structural integrity. However, transportation costs are extremely high on a per-unit-mass basis. As lunar population and demand increase, this method faces significant cost challenges. Additionally, module design must conform to launch vehicle capacity, limiting scalability. To address these constraints, inflatable modules are being developed to reduce stowed volume during transport while providing adequate habitable space upon deployment.
- In-Situ construction modules (ISRU + 3D Printing): This approach leverages local lunar resources and employs 3D printing technologies to construct structural components directly on-site. While more complex in terms of design optimization and equipment requirements, it offers substantial potential for reducing reliance on Earth-based material transport and achieving significant cost savings.

Looking ahead, it is likely that both supply methods will be adopted in a complementary manner—constructing primary structural elements using local resources, while integrating high-precision infrastructure components transported from Earth. Accordingly, this report assumes the utilization of in-situ technologies beginning in 2041 and 2036 for the nominal and optimistic scenarios, respectively. NASA awarded a $57.2M contract to ICON, a construction technology startup, under the Project Olympus initiative[11]. This program focuses on developing 3D printing technologies for building lunar infrastructure such as housing and roads. In parallel, Branch Technology, supported by NASA and in collaboration with Foster + Partners and Stanford University, has demonstrated research into 3D-printed walls and ceilings for habitation modules[12].

Reflecting these initiatives, the following structural composition is assumed once 3D printing technology becomes operational:

- Primary structural components (e.g., walls and ceilings, approx. 70%): Constructed on-site using 3D printing.
- Complex and high-precision components (e.g., electrical systems, docking mechanisms, precision machinery, approx. 30%): Delivered from Earth.



Credit: ESA

NASA's planned Foundation Surface Habitat (FSH) is designed to accommodate nominally two crew members, with a maximum capacity of four[13]. Similarly, reference cases such as Spartan Space's EuroHab[14] and the Moon Village concept developed by SOM and ESA[15] also assume a maximum capacity of four occupants per module. Accordingly, this report defines one habitation module as accommodating four people and estimates the required number of modules based on the total number of simultaneous lunar inhabitants.

Revenue structure

The revenue structure of the lunar habitation market comprises two principal streams:

- Accommodation Services: Provision of living space for astronauts and commercial visitors on the lunar surface.
- ISRU-Based Regolith for Construction: Sale of lunar regolith as a construction material for habitats and infrastructure.

These streams are closely interlinked: robust accommodation requires durable infrastructure, and ISRU-based construction using local regolith can significantly reduce dependence on costly Earth-supplied materials, thereby lowering long-term habitation costs. Demand projections for both streams are based on lunar visitor scenarios, which define the number of surface crew, their average duration of stay, and mission cadence through 2050.

Demand drivers and utilization architecture

Accommodation services

The pricing and development of lunar accommodation is shaped by a convergence of technological, logistical, and economic realities. To build a credible trajectory for this emerging market, three complementary estimation methodologies have been designed which, taken together, provide a unique perspective on possible price evolution.

01 **Multi-Analog Benchmarking** offers a market-driven ceiling, drawing from analogous domains such as ISS commercial astronaut visits, private orbital spaceflight, luxury adventure tourism, and high-end remote Earth accommodations. For context, NASA's official rate for private ISS visits is about $35,000 per night for life support and consumables[16], with private missions like Axiom's charging about $50–55M per person for a week-and-a-half stay—roughly $5M per day including launch and training[17]. Early space tourists on Soyuz/ISS flights paid several million per day for brief, exclusive trips. While such prices reflect scarcity and high prestige, they also establish a plausible upper bound for the first wave of lunar accommodation, where only a handful of pioneering individuals will participate.

02 **Engineering and Scaled Cost Modeling sets a more pragmatic economic floor** by calculating the minimum operational costs for maintaining a lunar habitat. Analyses combining both high- and low-cost scenarios, based on technology and research related to the BA-330 module (from Bigelow Aerospace) and a minimalistic outpost such as the Lavoie/Spudis habitat (NASA, Lunar & Planetary Institute), indicate that the operational costs for a lunar habitat range from approximately $50,000 to $268,000[18]. Notably, per-person costs decrease significantly as the number of modules increases, demonstrating the importance of scale and infrastructure sharing. However, these estimates generally exclude margins for profit, insurance, and standby costs for unused capacity, which are vital in a commercial context.

03 **ISS-Based Consumables Extrapolation** serves as a sanity check, translating known logistics and consumables costs for ISS missions to the lunar environment. On the ISS, the cost of daily consumables and delivery is already high; for lunar delivery, this rises steeply—data suggest that providing food, water, and oxygen to the lunar surface using Falcon 9 pricing leads to a daily consumable's logistics cost of over $200,000 per person. NASA's nominal all-in rate for private stays on ISS is $35,000 per day; when scaled to lunar logistics, an adjusted price of $178,000 per person per day is plausible. This approach, while simplified, further supports the finding that lunar accommodation will command daily prices in the high hundred-thousand.

Taken together, these three approaches triangulate a plausible range for early lunar accommodation pricing. Lunar accommodation is projected to begin around $300,000 per person per day in the pioneering phase (2026–2030), gradually decreasing as infrastructure and operations mature. By the late 2040s, a price point of around $100,000 per person per day becomes plausible, reflecting commercial normalization and advanced in-situ resource utilization.

A crucial but often overlooked aspect is the cost of keeping habitats operational and ready even when unoccupied. Unlike terrestrial hotels, lunar bases may sit idle for weeks or months between crews yet require continuous maintenance and energy. To reflect this, a standby or upfront infrastructure charge is needed—a placeholder value should be assumed. It should be noted that, in the last period of analysis, this figure significantly decreases as the base would be more frequently occupied, and this standby charge would not be necessary anymore.

ISRU-based regolith

The second pillar of the habitation market is the use of lunar regolith for construction. With the Moon, surface covered by trillions of tons of fine dust and rocky material, the challenge is not resource scarcity, but the technical and economic effort required to extract and process it in the harsh lunar environment. The true economic value lies in the cost and complexity of mining, processing, and delivering regolith.

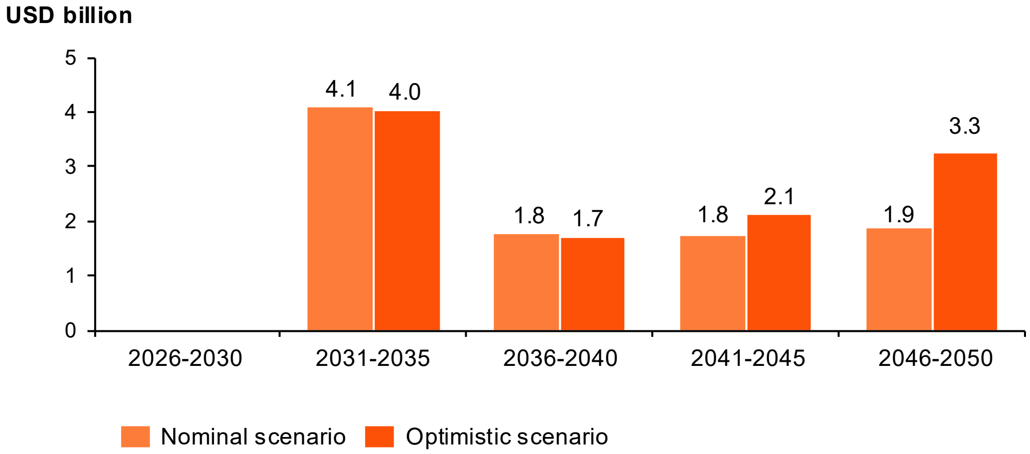
The adoption of ISRU regolith for construction is expected to start after 2041, as mission architectures evolve from importing all materials to leveraging local resources for cost reduction and sustainability. To estimate the price of lunar regolith, we applied a multiplier to terrestrial analogs—such as the price of crushed stone or gravel, typically $20–185 per ton on Earth—factoring in lunar-specific overheads: specialized equipment, energy supply, labor, maintenance, risk premiums, and the depreciation of infrastructure in a remote and extreme environment. This results in an estimated price range of $500–50,000 per ton for locally produced lunar regolith.

It is important to clarify that this price is for regolith processed and used on the lunar surface, not for materials transported from Earth, which can cost several hundred thousand dollars per ton or more due to launch and delivery expenses. The rationale is that, while initial ISRU costs will be high, they are expected to decrease over time as technology matures, production scales up, and operational efficiencies are realized. The market logic remains regolith itself is abundant, but its value is determined by the effort and cost required to mine, process, and utilize it in situ. As lunar infrastructure develops, these costs will become increasingly competitive compared to Earth-imported materials, supporting the transition to sustainable lunar construction.

Market Assessment

Investments assessment

The cumulative investment cost from 2026 to 2050 represents around $9.5B in the nominal scenario and $11.2B in the optimistic scenario. In both cases the investments peak in the coming years (2031–2035) and then decline progressively in subsequent phases, attributable to the fact that during in the early stages, habitation modules are developed and manufactured on Earth but also transported in their entirety to the lunar surface (in a completed or prefabricated state), with transport representing a substantial weight in the total costs.

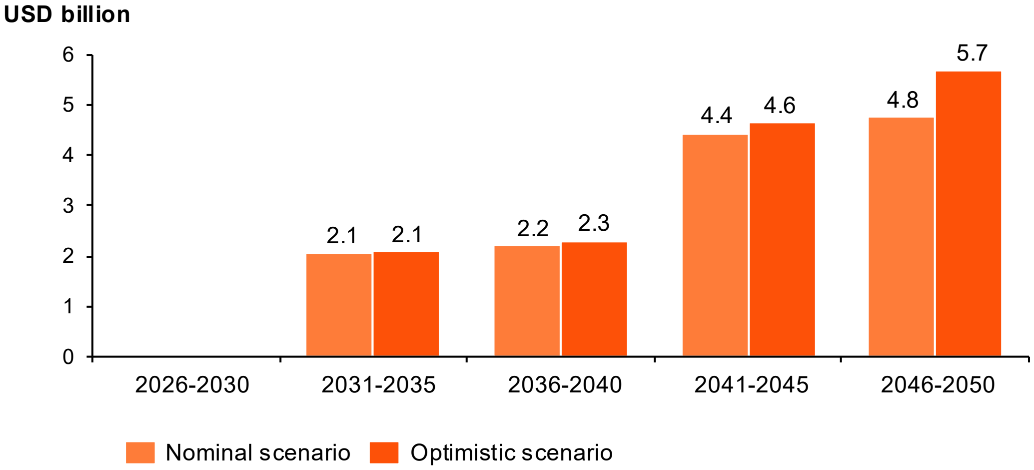


From 2041 onward (from 2036 in the optimistic scenario), in-situ construction using 3D printing technology is introduced. At that point, the primary structural components of habitation modules are produced on the lunar surface. As a result, transportation costs are substantially reduced, and manufacturing costs shift toward in-situ construction. This transition away from reliance on Earth-based supply chains becomes the principal driver of the overall decline in investment costs, in addition, to the anticipated reduction in the cost per kilogram of transportation itself, which significantly influences the total cost.

At the same time, operating expenditures are expected to rise as the number of habitation modules on the lunar surface increases with each phase. In the later periods, the deployment of regolith excavators and 3D printers will further expand the scope of infrastructure manufacturing, development, and operational costs.

Revenues assessment

In the early decades, accommodation will remain a premium, high-value service, mostly limited to government astronauts and a handful of pioneering private individuals. Revenues in this phase are a function of very high daily rates and low total occupancy—high exclusivity but low overall volume. As mission frequency increases and new modules are added, occupancy rates will rise, enabling more efficient use of infrastructure and the emergence of commercial providers. The gradual entry of private actors will add competition, potentially tiered accommodation offerings, and incentives for further cost reduction through reuse, ISRU, and automation.



The regolith market will develop in parallel but more slowly, with initial revenues tied to government procurement for key infrastructure projects and only later expanding to support broader commercial or even industrial uses. The key inflection point will come when the cost of using local regolith falls below that of importing terrestrial construction materials—a tipping point enabled by advances in mining, processing, and robotics.

Standby fees for maintaining habitats between missions will be essential for cost recovery. Overall, the total revenue opportunity is modeled at roughly $13.5 billion in the nominal scenario, with upside in an optimistic case driven by higher occupancy.

Credit: EuroHab, SpartanHab

Energy market

With the evolution of the mindset around lunar exploration from one-off, back-and-forth scientific missions toward a sustainable human presence and economic activity, the needs for energy are also shifting toward the combination of embedded Earth-sourced batteries and the local production and storage of energy. Energy becomes a foundational infrastructure for any lunar society to enable the scalability of the activities. It underpins all essential functions, including habitation, mobility, in-situ resource utilization, construction, communications, and scientific research and is therefore a critical enabler for the growth of the future lunar economy.

Assumptions and scope

Structure of Lunar Energy Demand

Energy on the moon will be needed for usages both internal and external to modules. Internal use designates the energy used within habitat modules on the surface, and external module use for activities across the rest of the ecosystem. These needs are segmented along four main categories which will drive the energy demand on the moon, differentiated by the types of end users:

Mobility

Energy consumed by rovers, which scales with vehicle size and mission frequency. The end users can be space agencies (NASA, ESA...), or commercial players either for tourism or experimentations.

Habitation

Power required for life support and accommodation systems. Includes also the energy for scientific experimentations inside modules. End users in this case can be the habitation providers or space agencies managing their own habitations.

Communications and Data centers

Operation of communication equipment and data centers. The energy consumed for communication inside modules is embedded in habitation energy estimates, while the energy for data centers is estimated separately. End users in this case are either the space agencies or commercial players.

ISRU

Energy for water and He3 extraction and 3D printing of habitat modules. Different end users can be targeted in this case. Habitation builders will require energy for the 3D printers, while water will be extracted for mobility (propulsion) and for life support.

The energy requirements for each of the four lunar infrastructure segments were assessed individually. This evaluation was based on three key factors: projected lunar population figures, the anticipated technological maturity across different time horizons, and available data on energy consumption by various systems and users (e.g., rovers, data centers, habitation modules, industrial machinery).

Following this demand analysis, the investment assessment focused on identifying and evaluating energy sources capable of meeting these needs. The cost estimation encompassed manufacturing, transportation to the lunar surface, and operational expenditures. Importantly, the analysis accounted for the varying levels of technological readiness, recognizing that not all energy solutions would be deployable from the initial phases of lunar development.

Revenue projections were derived by multiplying the estimated energy demand (in kWh) by a unit price per kWh. This price was benchmarked against NASA's estimated energy cost for commercial users aboard the International Space Station, adjusted by a proxy factor reflecting the cost differential between launches to the ISS and to the Moon.

Supply Architecture and Energy Sources

Lunar energy supply can be categorized into four key functions: generation, storage, transmission, and control.

01 Generation

- **Solar Power**: Converts lunar sunlight directly into electricity. It is lightweight, easily deployable, and expected to serve as the primary energy source in the early phases. However, its use is constrained at night and in polar regions.

- **Regenerative Fuel Cells (RFCs):** RFCs are viewed as a promising system for storing daytime solar energy and providing reliable nighttime power, capable of addressing long lunar nights and extreme day–night cycles.

- **Small Nuclear Reactors**: Fission-based systems that supply continuous, stable power independent of solar input. They are considered essential for operations during the two-week lunar night and in permanently shadowed regions.

02 Transmission

- **Wired Transmission**: Delivers electricity safely and efficiently through cables, providing the backbone for inter-module and intra-base power distribution.

- **Wireless Transmission**: Transmits electricity via electromagnetic waves without cables. It is considered effective in environments where cable installation is difficult and is expected to be useful for rovers and remote assets. However, as the technology is still under development, it is not included within the scope of this report.

03 Storage

- **Lithium-Ion Batteries**: A widely used storage solution suitable for short-duration supply, supporting equipment operations and nighttime use.

- **Regenerative Fuel Cells (RFCs):** Serve both as power generation and storage systems, positioned as a primary option for long-duration energy storage during lunar nights.

04 Control and Operations

- **Power Grids**: Provide the integrated control and management platform that connects generation, storage, and transmission. NASA is advancing the development of a lunar "microgrid" capable of flexibly integrating multiple sources, including solar power, small reactors, RFCs, and lithium-ion batteries[19]. To achieve this, a standard interface—the Universal Modular Interface Converter (UMIC)—is under development[19]. Once standardized, microgrids are expected to be gradually expanded, ultimately connecting major lunar bases into broader energy networks.

In the early stages, solar power is expected to be the primary energy source, complemented by lithium-ion batteries and RFCs for storage and backup generation. NASA has highlighted that solar power alone cannot sustain operations through the extended lunar night, and that a combination of lithium-ion batteries and RFCs enables a more reliable and practical power system[20]. By leveraging the complementary characteristics of each source, a stable supply can be achieved. This multi-source configuration is expected to form the foundation of lunar energy infrastructure and be applied broadly across major use cases such as habitation modules and large rovers. However, small rovers are generally battery-powered, and even mid-sized rovers typically rely on solar power combined with batteries, meaning the multi-source model is not universally applicable.

Looking further in the future, maintaining long-term human outposts will benefit from more robust and stable power sources that can survive the lunar night and operate in permanently shadowed regions. To this end, NASA aims to demonstrate a 40-kW class fission surface power (FSP) reactor on the Moon in the early 2030s[21]. Such a reactor is designed to support nearly all base-level energy needs, including habitation, ISRU facilities, rover charging, communications, and construction equipment.

The use of small nuclear reactors for operational use is assumed to take place after 2036 under the nominal scenario and in the early 2030s under the optimistic scenario. Once deployed, the reactor is expected to serve as the primary power source, meeting most of the energy demand. Solar power lithium-ion batteries, and RFCs will continue to play critical roles as supplementary sources, providing backup capacity and supporting remote applications (e.g., mobility vehicles, advanced scientific bases, remote ISRU capabilities). Accordingly, while the relative composition of the energy mix will change, the redundancy and stability ensured by a multi-source configuration will continue to be maintained.

Commercialization Timeline

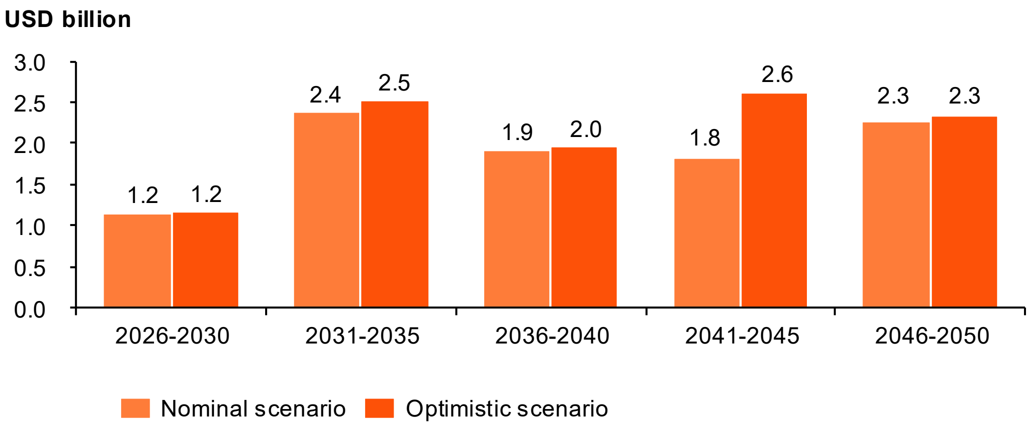
Energy is not commercialized before 2036. This aligns with:

- The expected deployment of nuclear and solar plants.
- The transition from government-led missions to mixed public-private operations.
- The emergence of demand from commercial users supplying services to institutional end users (e.g., private rovers, data centers).

Energy pricing is derived from ISS benchmarks, scaled by lunar transport costs. Prices are assumed to decrease over time, reflecting improved launch economics and infrastructure maturity.

Market Assessment

Investments assessment



The cumulative investment in energy from 2026 to 2050 is projected to reach approximately $9.6B under the nominal scenario and $10.6B under the optimistic scenario. In both scenarios, 2031–2035 represents the first investment peak, and another peak is observed in the 2040s.

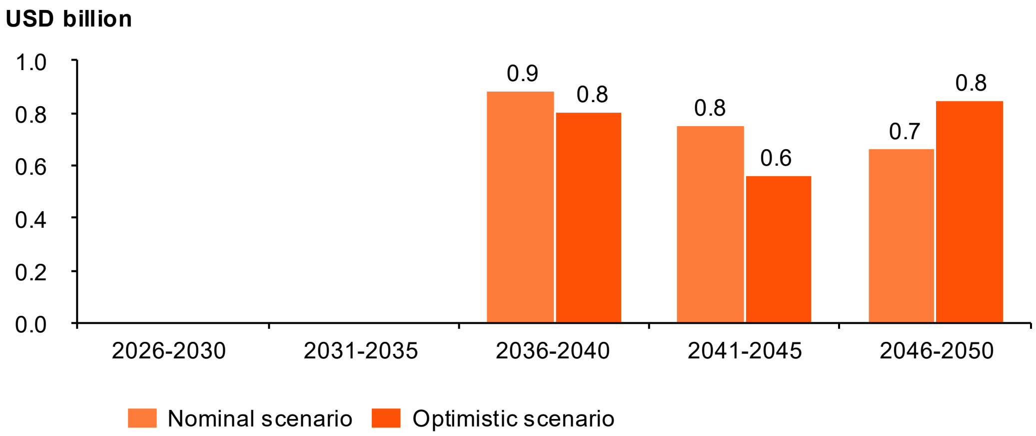
This first peak reflects a structural feature of the period: reliance on technologies available in the early 2030s—such as lithium-ion batteries, regenerative fuel cells, and solar power—which require a comparatively large number of units and relatively high mass per unit of energy supplied, resulting in elevated transportation costs. Moreover, in the early 2030s, the cost-reduction effects of launch services are still limited, further contributing to overall cost growth.

Under the nominal scenario, small nuclear reactors are assumed to enter demonstration and early deployment in the late 2030s, followed by full-scale deployment after 2041. Under the optimistic scenario, demonstration and early deployment are assumed to begin in the early 2030s, with full-scale deployment from the late 2030s onward. This assumption is based on NASA's stated goal of demonstrating and operating a 40 kw-class fission surface power reactor in the early 2030s[22]. Based on NASA's target of at least 10 years of operation, this report assumes a 10-year reactor lifetime and plans replacements ten years after initial deployment—i.e., 2046–2050 in the nominal scenario and 2041–2045 in the optimistic scenario—thereby driving higher investment in the later phases.

In parallel with the deployment of small nuclear reactors, the standardization of power interfaces through the Universal Modular Interface Converter (UMIC) is also expected to progress. This will enable the establishment of a flexible power grid capable of accommodating the expansion of modules and habitation areas. With the introduction of UMIC, multiple power sources—including nuclear reactors, solar power, and RFCs—can be integrated with diverse end-use systems such as habitats, ISRU facilities, and construction equipment, thereby achieving standardized interfaces and optimized power distribution. As a result, the overall energy supply system is expected to transition toward a more consolidated and efficient structure, and the lunar power infrastructure is expected to enhance reliability and scalability.

Based on the above, during the 2030s–2040s, as the number of lunar visitors increases, lunar exploration expands, and data centres begin to be established, the growing energy demand would involve significant mass and cost risks if met solely through solar, battery, and fuel cell systems. Therefore, the timing and feasibility of small nuclear reactor deployment are expected to become one of the main bottlenecks in securing lunar energy supply capacity and expanding the scale of surface habitation.

Revenues assessment



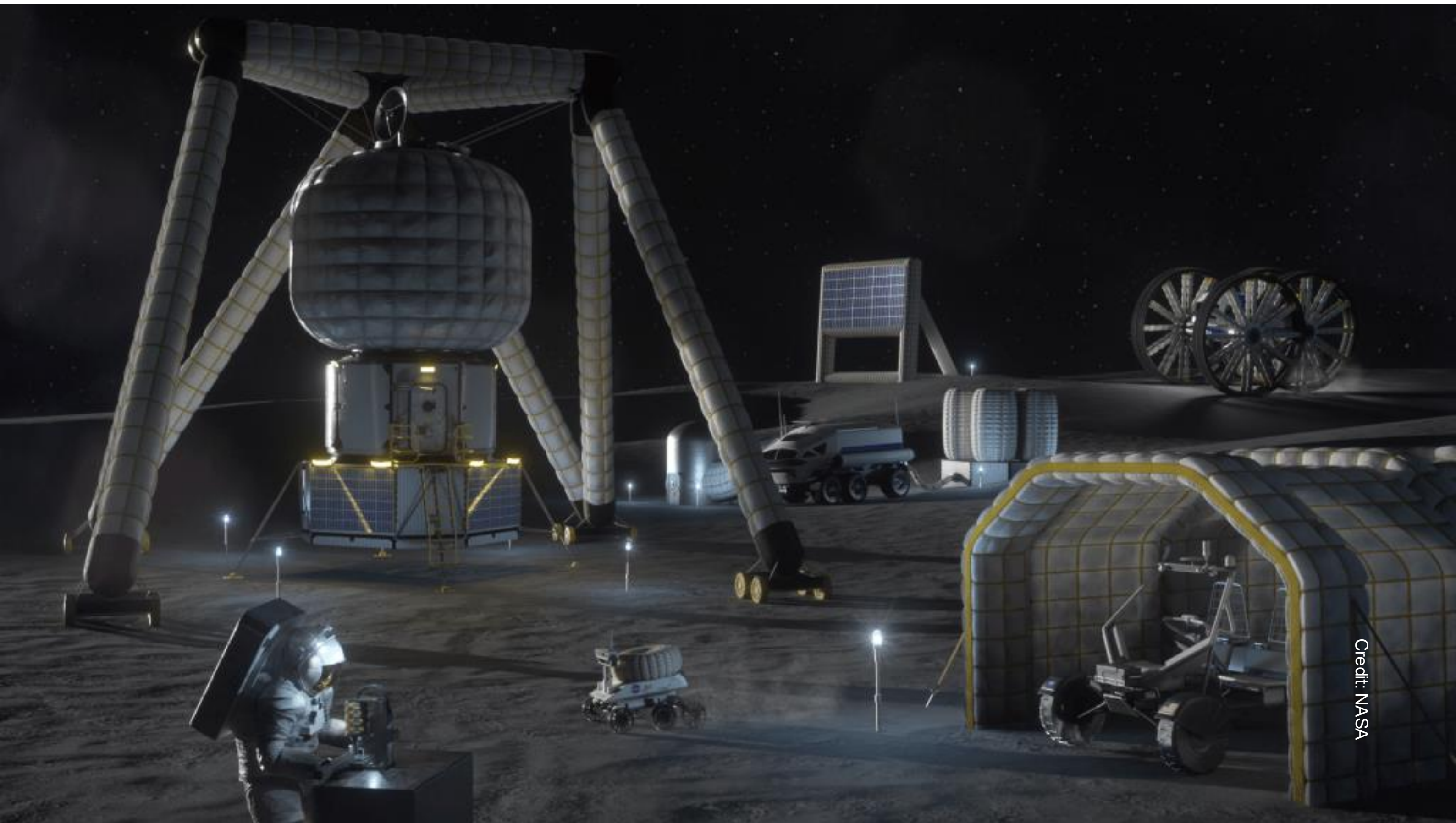
Energy revenues are projected to commence in 2036 under both scenarios, driven by the gradual availability of energy sources. Over time, the diversification and multiplication of these sources will offset rising demand, resulting in a significant decline in prices throughout the analyzed periods. Consequently, in the nominal scenario, despite increasing demand, revenues will steadily decrease, falling below $0.7 B during the 2046–2050 period. Cumulative revenues over the entire commercialization horizon are estimated at approximately $2.4 B in this nominal scenario.

On the other hand, although the optimistic scenario assumes higher demand, the impact is mitigated by lower prices. As a result, revenues remain slightly below the nominal case during 2036–2040 and 2041–2045. However, in the final period, demand accelerates to such an extent that, even with reduced prices, revenues surpass those of the nominal scenario. This outcome is largely influenced by the pricing model, which relies on a proxy incorporating parameters that decline more rapidly under the optimistic assumptions.

The Potential of Helium-3 as a Lunar Resource

Helium-3 stands out as one of the most promising resources in the context of lunar exploration and commercialization. On Earth, ^{3}He is highly valued for its applications in nuclear fusion research, neutron detection for security and non-proliferation, quantum computing, and advanced medical imaging. However, its availability on our planet is extremely limited, with natural reserves being both scarce and costly to extract—leading to prices that can reach millions of dollars per kilogram.

In stark contrast, the lunar regolith is believed to contain between one and three million tons of ^{3}He, deposited over billions of years by the solar wind. This abundance has sparked significant interest from both public and private sectors, with companies such as Interlune, AstroForge and OffWorld already developing technologies capable of processing up to 110 tons of lunar soil per hour—though this yields only a few grams of helium-3. The technical and economic challenges of extracting, processing, and transporting ^{3}He from the Moon to Earth remain formidable, but the potential rewards are substantial: even a small quantity of lunar ^{3}He could revolutionize clean energy production and other high-value industries. As a result, the race to unlock the Moon's helium-3 reserves is accelerating, positioning it as a key driver in the emerging lunar economy.



Credit: NASA

Water market

While various types of materials can be extracted from the lunar soil, water plays a precursor role considering both the stakes associated with its usages, and the higher maturity of technologies for extracting and processing it, with demonstrator missions already launched or planned in the coming years. Water is a foundational enabler of the future lunar economy, central to life support systems for astronauts, but also for the more economical supply of rocket propellant through in-situ resource utilization. As such, its value lies not only in cost reduction, but also in the higher resilience of the lunar economy through lower dependence on supplies from the Earth.

Assumptions and scope

Demand structure of the Lunar water market

The analysis of the demand for in-situ water is structured along two streams:

- Propellant production: the largest source of demand for water comes from the needs to produce liquid oxygen (LOX) and liquid hydrogen (LH_2) for rocket propulsion, particularly to refuel lunar landers and enable cislunar or Mars-bound missions. Local re-supply drastically improves the overall architecture of lunar missions, by increasing the available payload capacity for launchers aimed at the moon.
- Life support: This includes all water needed for human consumption (drinking, food preparation, hygiene) as well as water for hydroponic agriculture and other biological support systems. These applications are largely closed-loop, with high recycling efficiency (>95%). Hence, while net new water will always be required due to system losses and expansion of surface outposts, the total demand remains more limited in terms of volumes.

Demand estimates for both streams are rooted in the lunar visitor scenarios described previously, which forecast the number of astronauts (closely driving demand from life support) and missions (closely driving demand from propellant consumption). Under both nominal and optimistic scenarios, lunar water demand is initially modest but grows rapidly from the mid-2030s as ISRU systems begin operating at higher capacity and mission cadence increases.

Supply structure of the Lunar water market

Water supply on the lunar surface can be categorized into the following three sources:

01 Imported water from Earth: Water directly transported by launch vehicles from Earth. While this method ensures reliability of supply, the extremely high transportation cost imposes clear limitations on its sustainable use.

02 Recycled water: Water recycled within lunar systems, as illustrated by the Water Recovery System (WRS), which has been in continuous operation on the ISS for many years. The WRS purifies and recycles water derived from urine, sweat, and exhaled vapor. NASA has demonstrated recovery efficiencies of approximately 98%, and the system is expected to serve as a foundational technology for sustaining life in lunar modules.

03 In-situ Resource Utilization (ISRU): The technology to extract and utilize water ice believed to exist in permanently shadowed regions at the lunar poles. Thermal mining is regarded as a promising approach, whereby ice preserved at low temperatures is heated and sublimated to collect water vapor.

In the initial phase lunar water supply will rely entirely on imports from Earth and recycling systems. Recycling will be enabled by the ISS-proven WRS technology (with a recovery rate of ~98%), functioning as the core life-support technology. Imported water, on the other hand, will play a supplementary role—offsetting residual system losses and serving as the initial water source required for new modules, habitat expansion, and propellant procurement. The timing of ISRU deployment depends on the scenario. Under the nominal scenario, ISRU operations are assumed to begin after 2036 and to be fully operational from 2041 onward, whereas under the optimistic scenario, the roadmap is anticipated by 5 years. As will be shown later, during the periods when ISRU operations are marked as 'getting started', a simple 50% multiplier has been applied to the revenue estimates. This adjustment reflects the fact that initial revenues may begin to materialize, while full operational capabilities will only be reached at a later stage.

Credit: NASA, Plenty Unlimited Inc.

Demand drivers and utilization architecture

The economics of lunar water are fundamentally driven by the high cost of transporting materials from Earth to the Moon. In the early phases, the most relevant benchmark for ISRU-derived water is the cost per kilogram of delivering water (or equivalent resources) from Earth to the lunar surface, which remains extremely high—often exceeding $30,000 per kilogram for delivery to lunar orbit, and even more for the surface. As such, the primary strategic goal for ISRU ventures is to offer water at a price point that is competitive with, or lower than, the total cost of Earth-transported water to the Moon. While industry benchmarks such as United Launch Alliance's $3,000 per kilogram for propellant delivered to LEO illustrate the willingness of customers to pay a premium for critical resources in space, this figure serves mainly as an indicator of market willingness to pay, rather than a direct pricing proxy for the lunar surface. Over time, as ISRU technologies mature and production scales increase, the cost of lunar-derived water is expected to decrease significantly—potentially reaching the $2,000 per kilogram range. Achieving this level would make ISRU water not only economically viable but also the preferred option for supporting life support systems, refueling lunar landers, and enabling sustainable operations on and around the Moon.

This price evolution is crucial: it reflects the anticipated shift from a phase dominated by government procurement and technology demonstration toward a more competitive ecosystem, where commercial customers—particularly those needing propellant—begin to play a role. However, it is important to note that, for the foreseeable future, institutional agencies will remain the primary drivers of demand and market growth, with commercial activity building gradually on this foundation. As infrastructure scales and automation reduces operational costs, the price of lunar water is expected to decrease, but it will remain closely tied to the high costs of delivering resources from Earth for some time. While achieving a price point as low as $500/kg for ISRU-derived water would represent a major breakthrough, this figure should be seen as a long-term aspiration rather than an immediate benchmark. In practice, ISRU water will become competitive when it can undercut the total cost of Earth-transported water to the lunar surface—a threshold that will evolve in line with broader space logistics trends. As these dynamics play out, ISRU water will increasingly support both institutional and emerging commercial needs, enabling more sustainable lunar operations and, eventually, a more robust cislunar economy.

Life support

Water use for life support is anchored in NASA's extensive experience with closed-loop life support systems, particularly on the International Space Station. Astronauts require approximately 5–10 liters of water per day for drinking, rehydrating food, and personal hygiene[23]. Space farms or hydroponic systems for fresh food production add further demand, estimated at an additional 5–10 liters per square meter of crops per day[24]. However, advances in water recycling technology, already demonstrated on the ISS and in commercial vertical farming, enable up to 95–98% water recovery.

Thus, the net water requirement per astronaut is dramatically reduced: for a baseline of 10 L/day and 95% recycling, only 0.5 L/day of net new water must be supplied per astronaut, amounting to less than 200 liters per person per year. Hydroponic and controlled-environment agriculture, anticipated for lunar habitats from the 2030s onward, will operate at similar or even higher efficiency levels. NASA's life support research and commercial vertical farms (e.g., Plenty[25]) show that water use for space farming can be 90–99% lower than conventional agriculture. A closed-loop system could thus recapture nearly all irrigation water, with losses due mostly to transpiration and occasional system maintenance. Even as the lunar population grows, the absolute water requirement for life support remains relatively modest compared to propellant needs.

Propellant production

The production of rocket propellant from lunar water represents the most significant future driver of water demand. ISRU technologies, when mature, will allow extraction and processing of lunar ice into LOX and LH_2. The majority of modern lunar landers, including SpaceX's Starship HLS, Blue Origin's Blue Moon, and Dynetics' ALPACA, are designed to use either methane/oxygen (CH_4/LOX) or hydrogen/oxygen (LH_2/LOX) propellants. Across these architectures, oxygen typically accounts for 75–80% of the propellant mass, making the production of LOX from lunar water especially strategic. For example, NASA's Artemis architecture for human lunar landings uses Orion (crew module), the Space Launch System (SLS), and a human landing system (HLS). For Artemis III, Starship HLS is expected to require over 1,000 tons of propellant for a roundtrip, the majority being LOX. While much of this will initially be supplied from Earth, future missions aim to leverage lunar-derived oxygen—potentially reducing Earth-launched mass by up to 75%. Blue Moon and ALPACA landers are also designed for future compatibility with ISRU-derived fuels; Blue Moon, for instance, will eventually be able to refuel entirely with LOX/LH_2 produced on the Moon.

The ISRU production chain involves mining water ice, purifying it, and electrolyzing it into oxygen and hydrogen. Every kilogram yields about 0.89 kg of oxygen and 0.11 kg of hydrogen, enabling the production of either LOX alone or full LOX/LH_2 propellant on the lunar surface.

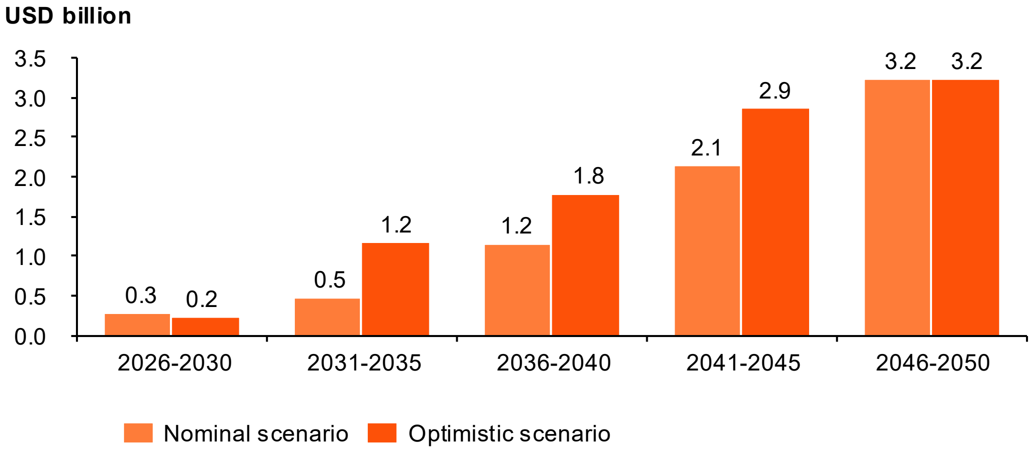
The scale of water required for propellant grows rapidly with mission cadence and the adoption of reusable or refuellable vehicles. For context, a single Blue Moon-class lander (~30 tons propellant) would require 37 tons of water to fully refuel. In the nominal scenario, where crewed missions ramp up slowly, ISRU-derived water is likely to supply only a portion of the propellant demand through the 2040s. In the optimistic scenario, more ambitious lunar exploration and the rise of commercial and international users would see the deployment of larger ISRU systems; potentially extracting and processing hundreds of tons of water annually by mid-century.

Market Assessment

Lunar water as a commodity is projected to reach commercial viability later in the period considered, as the first ISRU plants begin supplying government and, subsequently, commercial customers. Prior to this, water will remain a logistics expense absorbed into the cost of launching missions from Earth. Revenue generation starts when agencies or commercial operators begin paying for lunar-sourced water—primarily for propellant but also for habitat expansion and life support top-ups.

Investments assessment

Cumulative investment in the lunar water market from 2026 to 2050 is estimated at approximately $7.3B under the nominal scenario and $9.3B under the optimistic scenario. In both scenarios, the level of investment increases progressively with each phase, showing a steady upward trend, and the growth accelerates notably following the introduction of ISRU.



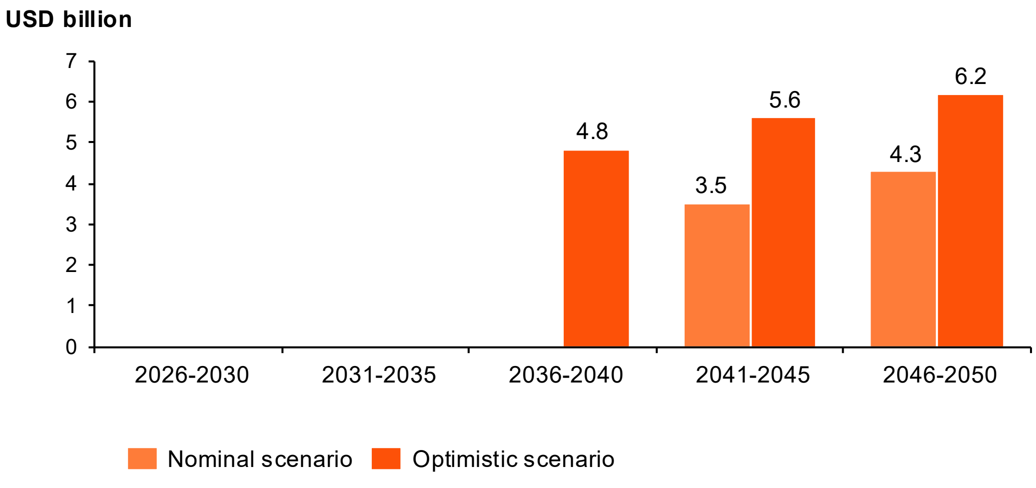
In the initial stage (prior to ISRU introduction), the supply of water depends primarily on transported water from Earth and recycled water, with transportation costs accounting for most of the total investment.

Subsequently, under the nominal scenario, demonstration and early operations of ISRU using thermal mining units begin during 2036–2040, followed by full-scale deployment from 2041. Under the optimistic scenario, demonstration and early operations start in the early 2030s, with full-scale deployment progressing in the late 2030s. These units have complex system architectures and face operational uncertainties in the lunar environment, resulting in relatively high R&D and manufacturing costs. Accordingly, ISRU is one of the primary drivers of investment growth, and its deployment timing determines the onset of large-scale investment surges. After ISRU deployment, demand for water for propellant production is expected to accelerate, leading to a gradual expansion in the number of thermal mining units deployed.

Furthermore, water recycling systems (ECLSS: Environmental Control and Life Support System), which are assumed to be installed in each habitation module, will increase in number with the growth in simultaneous lunar visitors, leading to a phase-by-phase rise in unit installations. In addition, the number of storage tanks for collected and recycled water will also increase with the introduction and expansion of ISRU, serving as another factor driving investment growth.

Revenues assessment

Revenue projections for the lunar water market are a direct function of demand (total kilograms supplied) and the prevailing price per kilogram. In the nominal scenario, where ISRU production and crewed mission cadence scale cautiously, revenue growth is steady but incremental. The first commercial sales may total only a few million dollars annually, gradually as more landers and crewed bases. In the optimistic scenario, the combination of greater mission frequency, earlier commercial participation, and the establishment of multiple ISRU plants drives faster revenue growth. Annual cumulative revenues could exceed $7.8B by 2050 in the nominal scenario, especially if lunar propellant sales support not only Artemis-class missions but also cislunar tugs, Mars-bound missions, and commercial activities which, however, have not been included in this analysis. Cumulative revenue from 2036–2050 could reach $16.6B in the optimistic scenario, more than double that of the nominal case.



It is important to note that these revenue forecasts are highly sensitive to assumptions around launch cost reductions, ISRU technology readiness, customer adoption, and the scale of lunar activity. Nevertheless, the dual-use nature of water, serving both life support and propulsion, gives it an outsized role in the overall economics of the lunar market.

04 Conclusion and future outlook

The rise of a lunar ecosystem will set a shift from isolated missions to a sustained, interconnected framework of infrastructure, services, and economic activity. More than a technological goal, it will be a systemic endeavor requiring aligned conditions and coordinated investments.

This ecosystem rests on five key pillars: mobility, communication, habitation, energy, and water. Each must achieve sufficient technological maturity and reliability, and their interdependence means synchronized development is crucial. Thus, several enablers are essential for the development of a sustainable lunar economy. One of the most critical is budgetary commitment, which has proven to be a recurring challenge in major space programs. For example, the Artemis program is currently experiencing funding uncertainty, highlighting how fragile financial support can impact timelines and ambitions. This underscores the need for stable, long-term investment—both public and private—supported by clear demand and viable business models. In addition, technological robustness is vital, especially given the harsh lunar environment, where delays in the deployment of habitats, ISRU systems, or nuclear power infrastructure could significantly hinder progress.

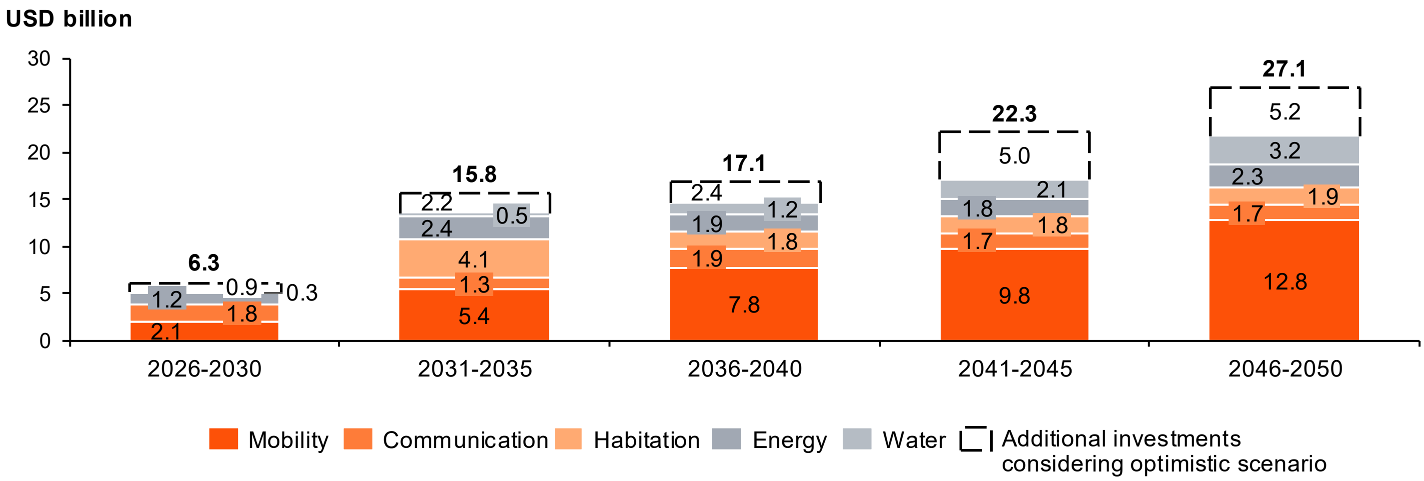
Regulatory clarity is another cornerstone. Current legal frameworks fall short, particularly around resource use and property rights. Clear rules, interoperable standards, and licensing regimes—like NASA's UMIC—are needed to foster investment and international collaboration.

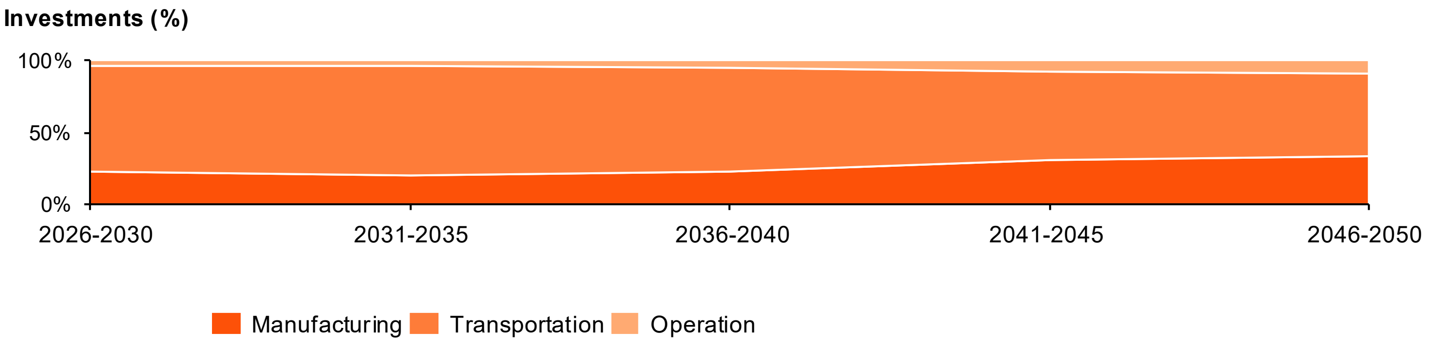
Investments summary

The cumulative investment from 2026 to 2050 is projected to reach approximately $72.7B to $88.5B. In both scenarios, investment expands consistently, reaching about $21.9B to $27.1B over 2046–2050. This indicates that infrastructure investment will steadily increase over the next 25 years in line with the progression of lunar activities.

The mobility market consistently holds the largest share, with the expansion of rover deployment driving investment. The communications market is characterized by heavy initial investment in infrastructure, followed by a shift toward maintenance and operations. The habitation modules market is initially burdened by reliance on Earth-based transport, but investment gradually declines with the introduction of 3D printing and on-site construction. The energy market experiences heightened investment in the early phase due to reliance on relatively inefficient power generation technologies; however, investment stabilizes in the latter period with the introduction of small nuclear reactors and standardized power interfaces. The water market initially depends on transported and recycled water, but investment surges with the introduction of ISRU, and continues to expand over the long term driven by increasing demand for propellant.

Two fundamental factors shape both the scale and structure of these investments.





First, the structural evolution of transportation costs. In the initial phase (2026–2035), transportation is expected to account for 70–80% of total costs. However, expanded rocket reusability and increased payload volumes on large-scale transport capabilities – as contracted by NASA from SpaceX and Blue Origin – are projected to reduce per-kilogram costs. By 2046–2050, transportation is expected to represent only 50–60% of total investment. Lower transportation costs will have a ripple effect across all markets, significantly improving long-term investment efficiency.

Second, investment efficiency gains driven by technological advancement. The adoption of 3D printing in habitation modules, small nuclear reactors and standardized power interfaces in energy, and ISRU in water are pivotal innovations that shift reliance from Earth-based transport toward in-situ resource utilization, fundamentally altering the nature of investment. Consequently, the timing and maturity of such breakthrough technologies will be decisive in shaping future investments for a sustainable lunar economy.

Revenue summary

The total cumulative revenues expected from lunar surface activities between 2026 and 2050 are projected to be in the order of $93.9B to $127.3B, when aggregating the revenue streams from the five market segments considered. The projections for the nominal and optimistic scenarios highlight the Moon's transformation from a purely scientific destination to a dynamic economic ecosystem, with revenues scaling up sharply in the 2040s as commercial markets mature and mission frequency increases. The overall magnitude of these revenues underscores the strategic importance of lunar development for both public and private stakeholders, positioning the Moon as a key driver of future space-based economic activity.

Overall, the lunar economy's revenue outlook is shaped first and foremost by the intensity of exploration missions, both crewed and uncrewed. The frequency of missions and the average presence of people on the surface will itself be conditioned by the pace of infrastructure deployment, and the readiness of commercial suppliers to demonstrate their solutions.

The value and impact of Lunar development

The significance of lunar development can be framed across two key dimensions. First, it delivers tangible benefits to Earth by applying technologies and knowledge cultivated on the Moon to address societal challenges and stimulate industrial growth. Second, it serves as a strategic steppingstone toward Mars exploration and broader deep-space missions. The Moon is not humanity's final destination; rather, it should be viewed as a gateway to deeper space exploration and a contributor to solving challenges on Earth.

Impact on Earth

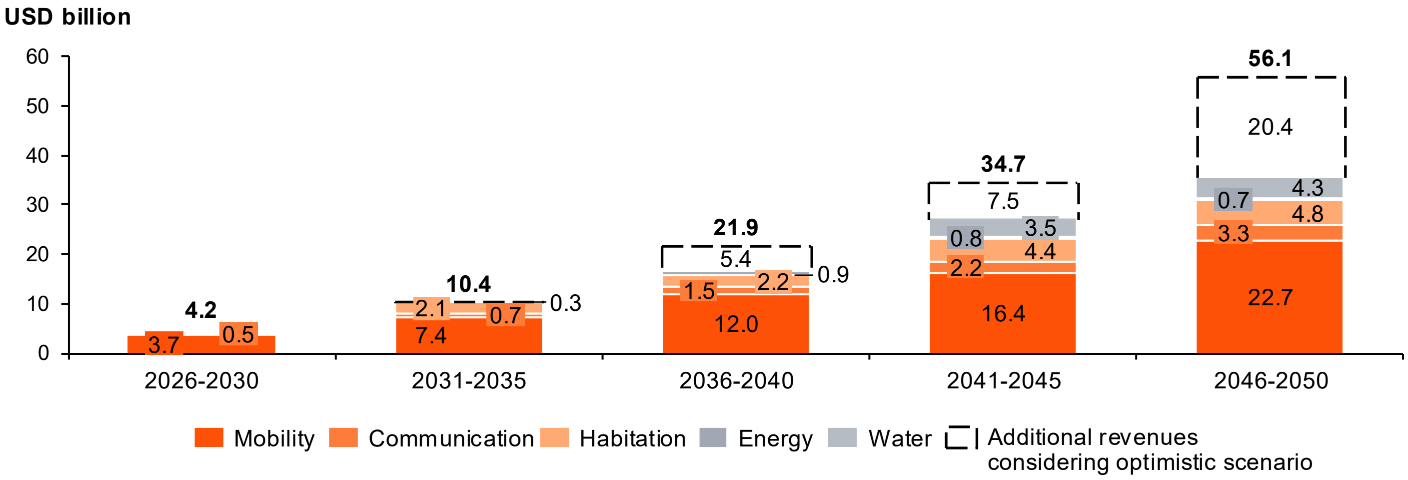
Lunar development brings diverse benefits to Earth's industries and society. The most prominent direct impact is the revenue generated by lunar business activities, which represents the most immediate and quantifiable outcome of the lunar market. As the revenue aspect has already been discussed, the following discussion focuses on broader impacts, organized into four key categories:

1 Application of technologies on the Earth

2 Utilization of Moon as testbed

3 Lunar resources on the Earth

4 Broader social impact



First, the impact of applying technologies developed for the Moon to Earth – Technologies refined to withstand the Moon's extreme conditions are expected to generate solutions for terrestrial challenges. For example, autonomous driving and durable materials developed for lunar rovers can support mobility in disaster sites and other harsh environments. Regenerative fuel cells designed to power lunar bases could also be applied to remote regions and emergency backup on Earth, while advanced water recycling systems, essential in closed lunar environments, may improve water security in arid regions and smart cities. In essence, innovations driven by lunar development are poised to deliver tangible societal and industrial benefits on Earth, with applications extending well beyond these examples.

Second, the impact of technological innovation is enabled by using the Moon as a testbed – The Moon offers a unique environment for developing and validating technologies that are either nascent or non-existent on Earth. Its extreme conditions—radiation, temperature fluctuations, and low gravity—are difficult to replicate on Earth, making it an ideal platform for large-scale testing. Technologies constrained by safety regulations or environmental restrictions on Earth can be demonstrated on the

Moon. For example, experiments in crystal growth and advanced material development under low-gravity and high-radiation conditions can enable research that is impractical on Earth, potentially driving innovation in industries such as pharmaceuticals and semiconductors. In communications, lunar demonstrations of next-generation standards such as 6G and 7G are expected to advance applications including holographic communications and remote robotic operations, validating performance in ultra-high-capacity, ultra-long-distance, and ultra-low-latency conditions. Furthermore, nuclear fusion is still under study globally, but large-scale lunar demonstrations could accelerate its maturity and bring forward commercialization.

Third, there are the potential benefits to Earth from the utilization of lunar resources – A representative example is helium-3. Deposited in the lunar regolith by the solar wind, it is regarded as a promising aneutronic fusion fuel that produces minimal radioactive waste and could support global energy security and decarbonization. Beyond energy, helium-3 is also an essential resource in advanced technology fields, serving as a cryogenic coolant for quantum computing, a critical element in high-resolution MRI, and a key material in radiation detection systems. Given its extremely limited availability on Earth, a supply derived from the Moon could act as a catalyst for innovation and market expansion. Moreover, its economic value is considered exceptionally high, with estimates suggesting that it could reach tens of millions of dollars per kilogram[26]. Even limited quantities transported from the Moon could generate substantial economic returns. In this way, the utilization of lunar resources on Earth could drive technological innovation, industrial development, and the creation of diverse new value streams.

Fourth, the broader social impacts of lunar development – Lunar exploration inspires curiosity and aspiration in society, fostering greater interest in science and technology. It also motivates younger generations to pursue STEM careers, strengthening the foundation for long-term talent development. In addition, progress in lunar development generates new opportunities for industries, investment, and employment, acting as a driver of socio-economic growth. Internationally, cooperative frameworks such as the Artemis Program encourage collaboration among nations and can serve as models for addressing other global challenges. As lunar activities expand, the importance of establishing global laws, treaties, and governance mechanisms for security and conflict prevention will increase. Such frameworks not only reinforce international cooperation but also provide businesses with a predictable operating environment, encouraging sustained investment and market formation.

Impact on space exploration

Lunar development is not the ultimate destination but serves as a strategic and incremental step toward Mars exploration and broader deep-space missions. In NASA's "Moon to Mars" architecture, sustained human presence and infrastructure on the Moon are positioned as the foundation for future missions to Mars. While a Mars mission requires several years and makes return to Earth highly challenging, the Moon can be reached within days, providing a practical environment to validate exploration concepts and operational methods step by step. Although its environment and gravity differ from those of Mars, the Moon's isolation and harsh conditions offer a valuable testbed for assessing the performance and reliability of critical systems, with technologies developed there regarded as extensible to Mars[27]. Consequently, lunar activities represent not only scientific exploration but also the starting point for expanding humanity's sphere of activity from Earth into deep space.

In conclusion, lunar development is not merely an exploration activity. It lays the foundation for humanity's expansion into deep space while simultaneously generating wide-ranging impacts for Earth in the form of technological innovation, industrial growth, international cooperation, and talent development. Activities on the Moon should therefore be recognized as a strategic step in extending humanity's sphere of activity, as well as a social investment that underpins sustainable development on Earth.

References

1. PwC, “Lunar Market Assessment,” PwC France, 2021.
2. Japan Aerospace Exploration Agency, "Leaflet LUPEX.”
3. C. A. O’ Shea, "NASA Pursues Lunar Terrain Vehicle Services for Artemis Missions," NASA, 2023.
4. A. A. Donaldson, “NASA Selects Companies to Advance Moon Mobility for Artemis Missions,” NASA, 2024.
5. Intuitive Machines, “Intuitive Machines Expands Data Transmission Services for Lunar and Deep Space Missions,” December 2024.
6. Global relocate, “Internet Cost Ranking by Country.”
7. PwC analysis of price data.
8. Spartan Space, “Project EuroHab.”
9. Moon Village
10. The Aerospace Corporation, “Aerospace patents revolutionary lunar habitat concept,” 2021.
11. B. Bauguess, “ICON to develop lunar surface construction system with $57.2 million NASA award,” ICON, 2022.
12. Pro Builder, “Building homes on the moon: It’s possible with innovative 3D printing,” November 2022.
13. C. Burke, et al., “Internal Layout of a Lunar Surface Habitat,” NASA Technical Reports Server, 2022.
14. K. Kim, et al., “Internal conceptual system design of an inflatable lunar surface habitat, Eurolab”, IAC, 2022.
15. A. Pickering, et al., “Conceptual Design of a Lunar Habitat,” ESA, 2020.
16. BBC, “Nasa to open International Space Station to tourists,” 2019.
17. J. Kelvey, “Private crew who paid $55m per seat were exhausted by ‘frenetic’ workload in space,” Independent, 2022.
18. T. J. Colvin et al., “Demand Drivers of the Lunar and Cislunar Economy,” IDA, 2020.
19. G. Thomas et al., “Lunar Microgrid Trade Studies to Define Interface Converter Requirements,” NASA, 2023.
20. J. Cashman et al., “Regenerative Fuel Cell Systems for Lunar Surface Applications,” NASA, 2022.
21. E. Bausback, “NASA’s Fission Surface Power Project Energizes Lunar Exploration,” NASA, 2024.
22. NASA, “Fission Surface Power.”
23. M. K. Ewert, “Astronaut Mass Balance for Long Duration Missions,” NASA, 2019.
24. M. Wheeler, “Bioregenerative Life Support for Sustainability in Space,” NASA, 2022.
25. L. Hall, “NASA Research Launches a New Generation of Indoor Farming,” NASA, 2021.
26. AKAP Energy, “BBC Puts Helium-3 Price at US$96k/gram,” 2025.
27. J. F. Connolly et al., “The Moon as a Stepping Stone to Human Mars Mission,” NASA, 2018

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