9th Moon Village Association Workshop & Symposium

Lunar Industry Development

- Giant Leaps, Small Steps -

Study Phase 1

Industry Working Group (IWG)

December 3, 2025

IWG Members


- Co-chairs
  - Satoru Kurosu, MVA Board of Directors and Moon Market Development Coordinator
  - Mr. Atsushi Saiki, Executive Fellow, ispace, Inc.
- Members
  - Ms. Misuzu Onuki, Executive Vice President, SPARX Asset Management Co. Ltd.
  - Mr. Kiho Fukaura, Unit Leader, Lunar Plant Unit, DX Technology Exploration Group, Digital Project Delivery Department, JGC Corporation
  - Mr. Jeffrey Max, CEO, Magna Petra Corp
  - Mr. Yosuke Enomono, Senior Manager, PwC Consulting LLC
  - Mr. Issei Mamiya, Senior Corporate Strategy Specialist, Corporate Strategy group, ispace, Inc.
  - Mr. Hassan Abou Seada, Director of Frequency Coordination Department, Egyptian Space Agency (EgSA)
  - Mr. Lari Cujko, Startup Program Lead, esric (Co-Chair, MVA Lunar Trade & Investment WG (Lunar Commerce and Economics WG))
  - Mr. Christophe Bosquillon, CEO, Autonomous Space Futures Ltd (Co-Chair, MVA Lunar Trade & Investment WG (Lunar Commerce and Economics WG))
  - Ms. Shima Suresh, Business Development Manager, 3IPK (MVA, Moon Market Development Coordinator Support)
  - Dr. Yosuke Yamashiki, Professor, Chairperson of Division, Chairperson, SIC Human Spaceology Center

IWG Introduction

- Background
  - The rise of lunar development by both space agencies and private companies is accelerating the emergence of a new lunar industry. While long-term investments and significant funding are required, bold, opportunity-driven thinking is essential to transform potential into viable business.
- Goal
  - Position the lunar industry as a high-growth sector by providing concrete projections and a clear roadmap.
  - Furthermore, leverage lunar- derived technologies to address Earth-based challenges, fostering new business opportunities both on the Moon and on Earth.

Agenda

- Why Lunar Industry?
- Potential Business Segments
- Initial Industry Case Study: *What is the first "Small Step"?*
- Industries to Emerge Following Initial Infrastructure
- Industry Roadmap
- Conclusion and Next Steps

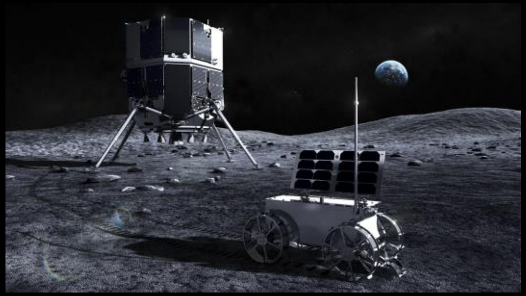
Commercial Moon Rash!

Intuitive Machines IM-1
Landed in Feb. 2024
©NASA

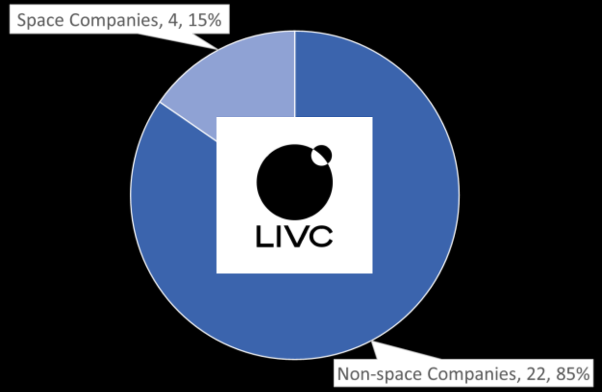
Intuitive Machines IM-2
Landed in Feb. 2025
©NASA

SORA-Q (LEV-2), the world's smallest and lightest transformable lunar exploration robot, developed by JAXA, TAKARATOMY, SONY and Doshisha Univ. ©JAXA

Firefly Aerospace Blue Ghost M1
Landed in Mar. 2025
©NASA



ispace M2
Attempted to land in Jun. 2025
©ispace



Non-space companies are joining the space industry
(Corporate members of Lunar Industry Vision Council)

Completed in 2025

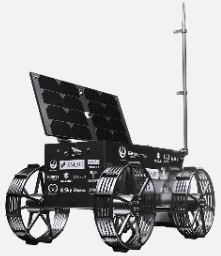
Mission 2 Overview

ispace

Hardware

RESILIENCE

- Size: Approx. 2.3m tall by 2.6m wide (legs deployed)
- Mass: Approx. 1,000kg (Wet: fully fueled), Approx. 340kg (Dry: unfueled)
- Design Payload Capacity: Up to 30kg



TENACIOUS™

- Design: Lightweight to withstand vibrations during transit to the lunar surface
- Mass: approx. 5kg
- Design Payload Capacity: up to 1kg

Highlights

- An R&D mission aimed at verifying technologies related to lunar landing and lunar exploration
- Although the final lunar landing was not achieved, the mission successfully demonstrated reliable transportation capability to lunar orbit
- The cause of the landing failure was a hardware issue in the laser range finder (LRF)
- Corrective actions will be made to incorporate further improvements into subsequent missions, including a review of the landing sensors and expanded technical support from JAXA
- As for payload contracts, the net sales to be recognized decreased by $1.5Mn to a total of $14.5Mn; however, no refunds or compensation for damages were incurred, and the financial impact of the failed landing is limited
- Recorded our first data service net sales of ¥23Mn in Q1

Payload Customer Sales Completed

Total net sales:
$14.5Mn(1)

Takasago Thermal Engineering, euglena, BANDAI NAMCO

P : Private-sector A : Academia G : Government

(from the left)

- P Takasago Thermal Engineering: water-splitting experiment
- P euglena: lunar algae-cultivation equipment
- A National Central University, Taiwan: deep space radiation probe
- P BANDAI NAMCO: “GOI Space Century Charter” plate
- P Artist, Mikael Genberg: Moonhouse (artwork)

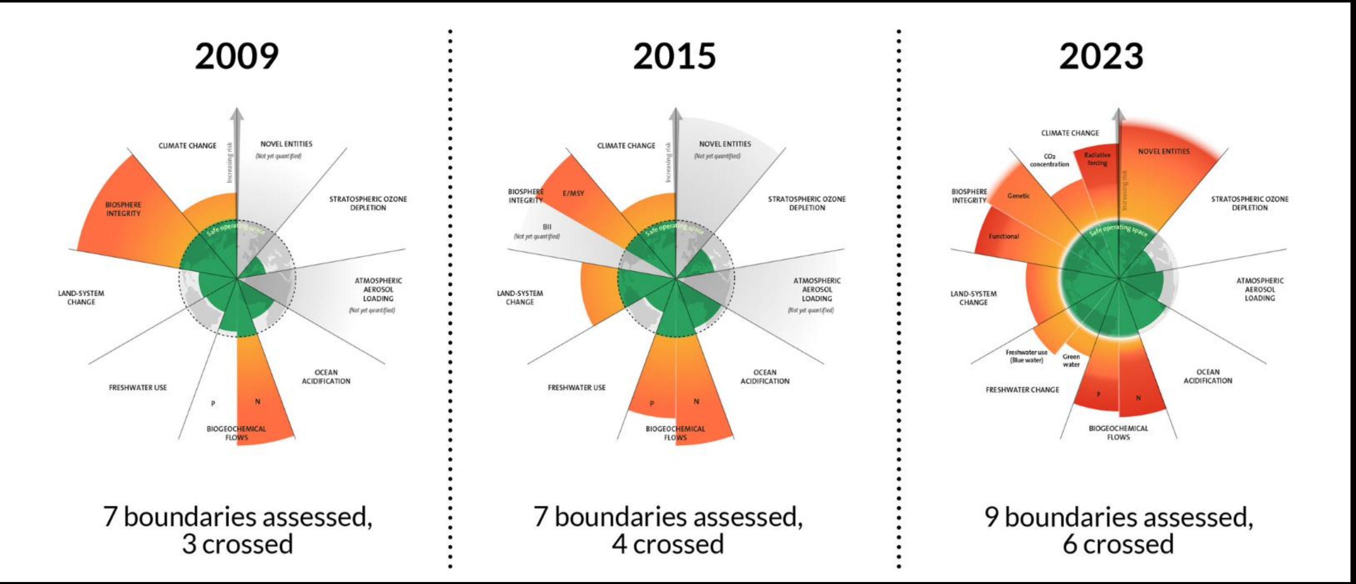
(1) As of August 8, 2025. Numbers are rounded down to the nearest whole number. Of the total contract amount of $16Mn, $1.5Mn was not received due to the incomplete lunar landing, resulting in a decrease in recognition of total net sales.

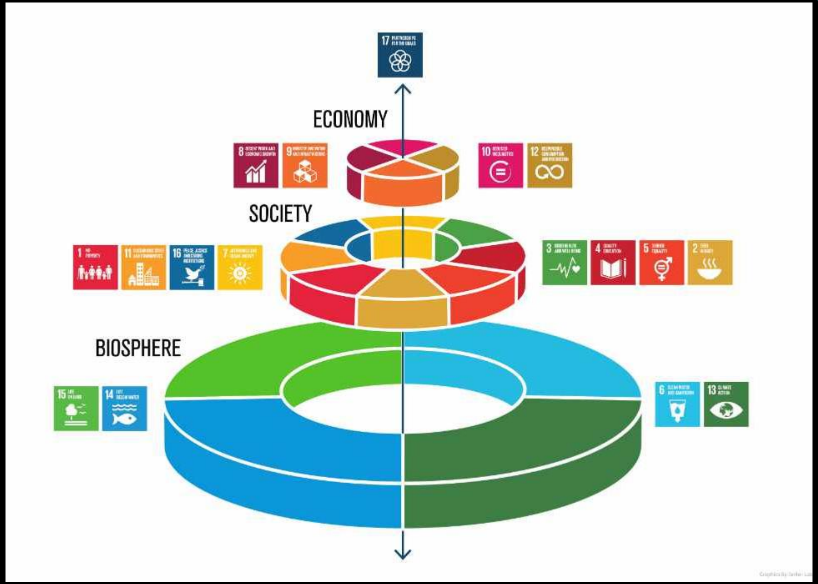
2025/5/27 Earth Rise（©ispace）

Why Lunar Industry?

"If we continue with business as usual, by 2030 we will need the equivalent of two planets to maintain our lifestyles.“ *WWF Living Planet Report 2010*

Exceeding Planetary Boundaries



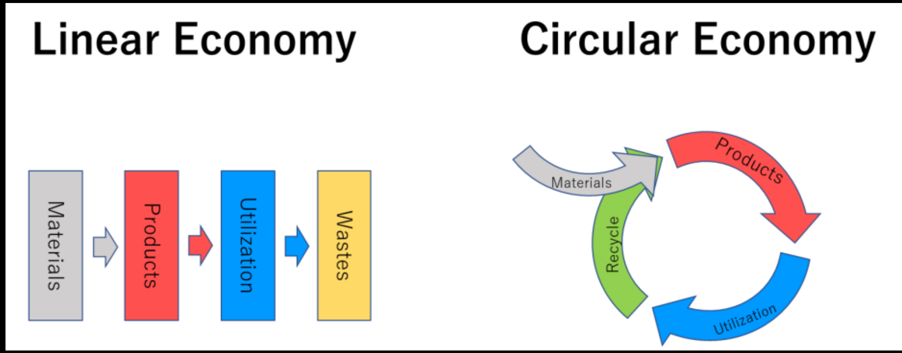


- Impact and Damage to Nature – Biosphere
- Climate Change and Global Warming
- Resource Depletion

How can we live without harming nature — the biosphere?

Why Moon?

- A unique testbed for developing sustainable technologies for Earth, independent of natural ecosystems
  - No fossil energy resources and limited supply from Earth
  - A cradle for Circular Economy driven by the ultimate 3R (Reduce, Reuse, and Recycle) requirements



- A proving ground for space-based resource utilization
- Driving innovation as a frontier of technology development, inspiring STEM education and creating new jobs on Earth

Moon is the first frontier for expanding industry into space

- 6-9 months to go
- 25 minutes communication delay

If Earth were the size of a soccer ball (22 cm),
How far are the Moon and Mars?

Mars:3.9km

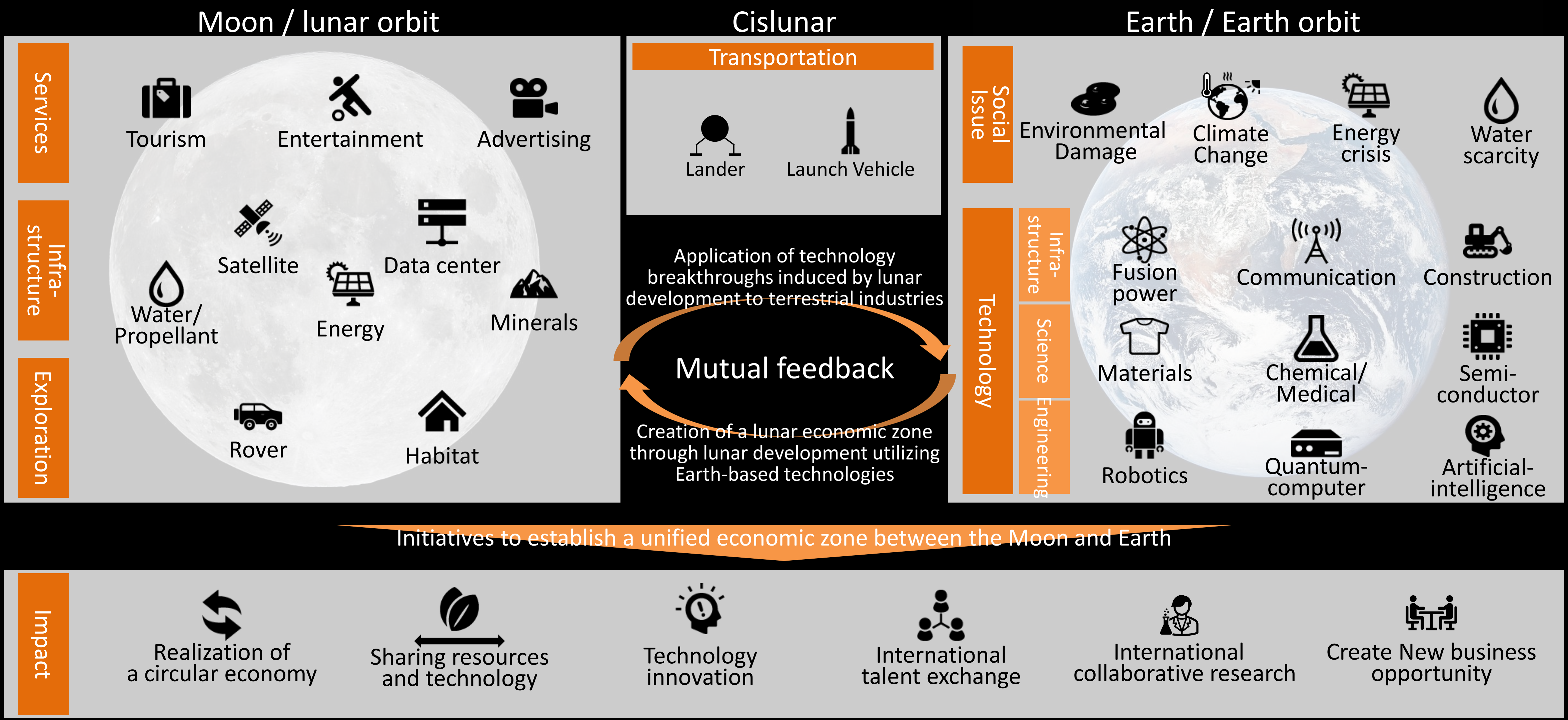
- 3 days to go
- 3 seconds communication delay

In space, the Moon is the nearest potential industrial site with a solid surface.

Note: Distances are averages and numbers are approximate.

Moon:6.6m

Potential Business Segments



Potential Resources

- Water
- Energy
  - Hydrogen and Oxygen
  - Helium-3
  - Solar
- Metals
  - Base: Iron, Aluminum, Silicon
  - Precious and Rare: PGM, Titanium, REE
- Soft (Intangible) Resources
  - Data & Information Services (Lunar Data Center)
  - Tourism
  - Advertising and Entertainment

Certain resources may serve as potential supplements to those on Earth.

IWG Study on Water-related resources

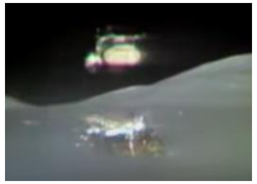
- Water-related resources (H_2, O_2, H_2O) extracted from regolith can be broadly categorized into water for **domestic use** and water for **industrial use.**
- Since domestic water is basically recycled, **the main market is assumed to be industrial water, with propellant being the largest segment.**
- As for the main demand for propellant, two types are assumed: ①**Ascender** and ②**Hopper.**

Products generated from water-related resources

- **Water-related resources extracted from regolith**
  - **Domestic Use**
    - Drinking water (H_2O)
    - Sanitary use (H_2O)
    - Breathing air (O_2)
  - **Industrial Use**
    - **Propellant (Liquid O_2 and H_2)**
    - Plant production (H_2O)
    - Fuel cells (H_2, O_2)
    - Others (e.g., Metal processing)

Major propellant users

Ascender (Return Vehicle)



Screenshot from a Smithsonian National Air and Space Museum video https://www.youtube.com/watch?v=9HQfauGJaTs

For crewed missions, a return Ascender is essential. Additionally, an uncrewed Ascender is required for sample return missions.

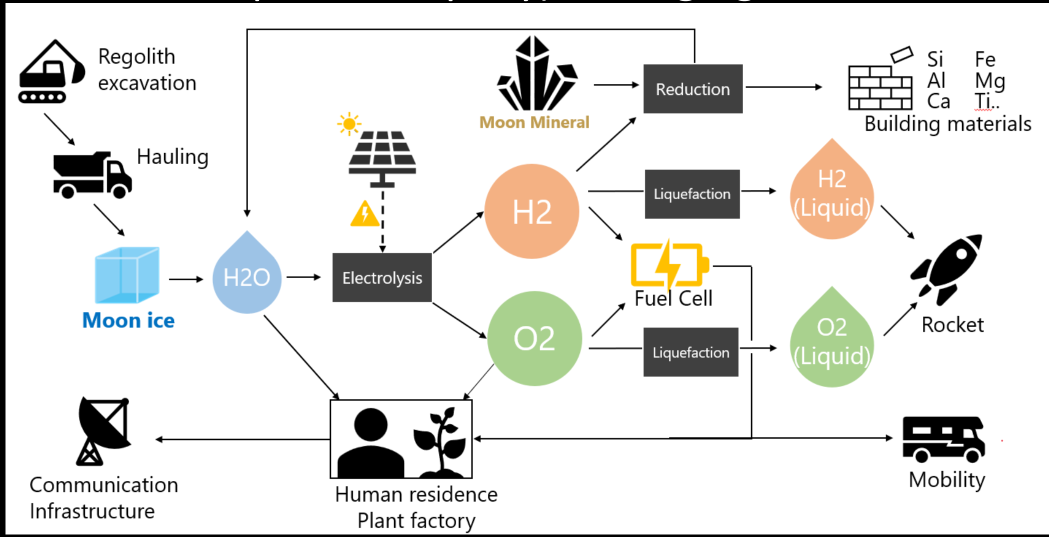
Hopper

Intuitive Machines, Micro Nova https://www.intuitivemachines.com/micro-nova

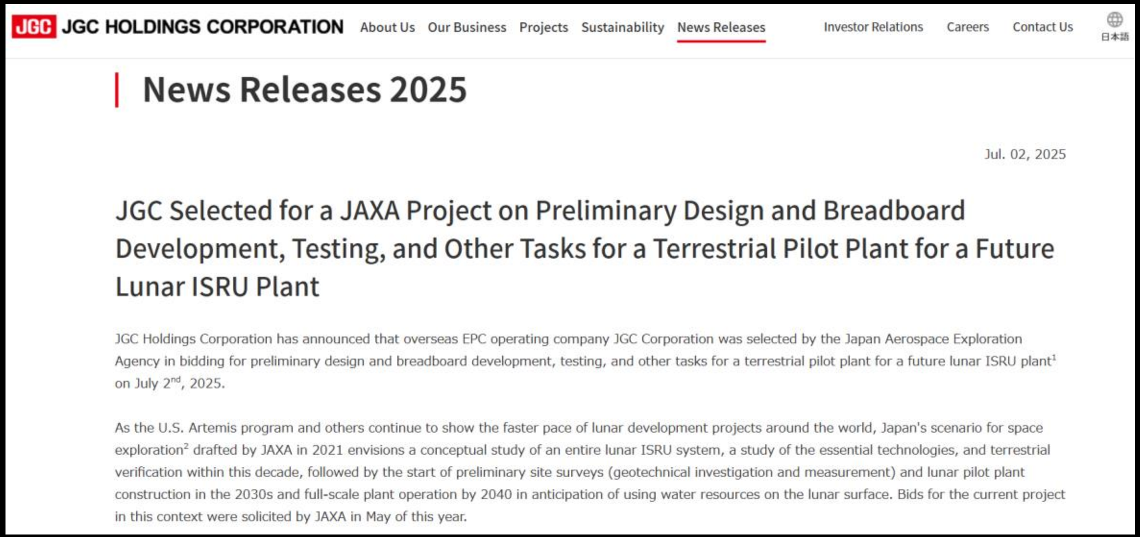
To support wide-area exploration and the future expansion of operational areas, hoppers (equipped with base stations, etc.) are expected to appear early on. In the future, the emergence of crewed hoppers is also anticipated.

What is the first *"Small Step"*? -ISRU Plant Overview-

- ISRU plays a key role in building a sustainable lunar economy and enabling broader national space exploration missions.
- Domestic Development Status
  - Since FY2021, JGC and JAXA have jointly developed concepts and prototypes for a Lunar ISRU Plant, focusing on the propellant plant, progressing from basic studies to pilot plant design and testing; By FY2025, development has progressed to the basic design phase of a terrestrial pilot plant.
- Business Development
  - From a private sector perspective, the business model may start with government-led infrastructure development and gradually shift toward private-sector-driven operations, such as an SPC (Special Purpose Company) managing lunar infrastructure.



Outline for ISRU Plant
(JGC Corporation, The concept of Architecture for the realization of sustainable Lunar Society based on water ISRU plant, IAC-25-4, 11, x99390, September 2025)


JGC HOLDINGS CORPORATION About Us Our Business Projects Sustainability News Releases Investor Relations Careers Contact Us 日本語

News Releases 2025

Jul. 02, 2025

JGC Selected for a JAXA Project on Preliminary Design and Breadboard Development, Testing, and Other Tasks for a Terrestrial Pilot Plant for a Future Lunar ISRU Plant

JGC Holdings Corporation has announced that overseas EPC operating company JGC Corporation was selected by the Japan Aerospace Exploration Agency in bidding for preliminary design and breadboard development, testing, and other tasks for a terrestrial pilot plant for a future lunar ISRU plant[1] on July 2nd, 2025.

As the U.S. Artemis program and others continue to show the faster pace of lunar development projects around the world, Japan's scenario for space exploration[2] drafted by JAXA in 2021 envisions a conceptual study of an entire lunar ISRU system, a study of the essential technologies, and terrestrial verification within this decade, followed by the start of preliminary site surveys (geotechnical investigation and measurement) and lunar pilot plant construction in the 2030s and full-scale plant operation by 2040 in anticipation of using water resources on the lunar surface. Bids for the current project in this context were solicited by JAXA in May of this year.

News Release, Jul. 02, 2025, JGC Corporation
(https://www.jgc.com/en/news/2025/20250702_11.html)

Year, Mass and Sales Price to Recoup Initial Investment on the Propellant Plant

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If transportation costs are reduced to one-tenth of the CLPS price and the plant facilities can be constructed within a total weight from 30 to 50 tons, then assuming the sales price is set at half of the transportation cost, investment recovery would be achievable in approximately three to five years.

Contents			Nominal Case
Needs	Ascender (Human Flight)	Frequency	1 / year
		Fuel Consumption per use (Liquified H_2+Liquified O_2=5.3t+31.5t)**	36.8t
		Fuel Consumption per use (H_2O)**	**48.0t**
	Ascender (Cargo Flight: Sample return)	Frequency	1 / year
		Fuel Consumption per use (Liquified H_2+Liquified O_2=5.3t+31.5t)**	36.8t
		Fuel Consumption per use (H_2O)**	**48.0t**
	Exposed Hopper	Frequency	1 / year
		Fuel Consumption per use (Liquified H_2+Liquified O_2=3.0t+17.8t)**	20.8t
		Fuel Consumption per use (H_2O)**	**27.1t**
	Annual Total Consumption		**123.1t**
Cost	Transportation Cost (Earth→Moon)		$0.1M/kg
	Propellant Plant Mass		30-50t
	Development Cost		$1B
	Initial Cost		**$4-6B**
Sales	Seles Price (50% of Transportation cost)		$0.05M/kg
	Annual Revenue		$6.16B
	Annual Profit (20% Margin)		$1.23B
	Payback Period		**Approx. 3-5 years**

Demand is assumed to be limited to the minimum level of government requirements. However, if additional commercial demand—such as fuel supply for XGEO satellites or tourism—accumulates, investment recovery could be achieved in a shorter timeframe or allow for a lower sales price.

Propellant Plant Mass (kg)
- Extraction: 210
- Electrolysis: 1,000
- Liquefaction(O2): 1,000
- Liquefaction(H2): 850
- Storage: 700
- Sub Total: 3,760
  (Power consumption: 138kW)

Power Plant Mass (t): 23-33
Total Mass: 26.76-36.76t

Source: Tanaka Y., Fukaura K., et al.: *Evaluating the value and feasibility of Lunar ISRU plants including power supply facilities*, 76th International Astronautical Congress, (2025)

FYI: Equation

- The recoup period for investments is crucial, and this can be evaluated primarily based on the propellant plant mass [kg], transportation cost [$/kg], propellant sales price [$/kg], and propellant sales volume [kg], as well as by setting a profit margin that takes into account Opex. (such as electricity and communication costs).
- To examine the plant mass constraints required to achieve the desired investment payback period as discussed above, the following equation was established.

  - $Plant\_Mass$: Mass of propellant plant[t]
  - $Transportation\_Cost$: $1k/kg～$1M/kg, based on SpaceX study in LunA-10
  - $Fuel\_Consumption\_Mass$: Annual propellant consumption (Needs) [t]
  - $Sales\_Prise$: Normally the half of the transportation($= Transportation\_Cost/2$), based on LunA-10 Study
  - $Profit\_Margin$：Normally set as 20% (depends on Opex)
  - $Payback\_Period$ ： Year to recoup investment [year]

The above variables are expressed by the following equation.

- $Plant\_Mass \times Transportation\_Cost < Fuel\_Consumption\_Mass \times Sales\_Price \times Profit\_Margin \times Payback\_Period$

$$\rightarrow Plant\_Mass < \frac{Fuel\_Consumption\_Mass \times Payback\_Period}{2}$$

Industries to Emerge Following Initial Infrastructure

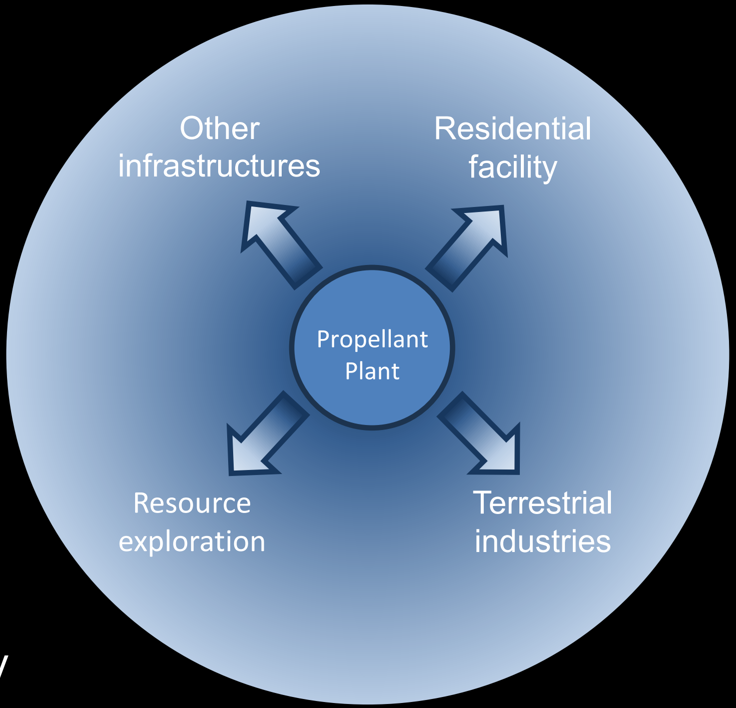
(1)Infrastructure construction
- ①Buildings
- ②Construction material plants (aluminum, titanium, etc.; material production and oxygen generation)
- ③Power generation (solar, nuclear), energy storage
- ④Communication, positioning

(2)Residential facility services
- ①Air, drinking water, food supply
- ②Transportation
- ③Governance
- ④Security
- ⑤Troubleshooting

(3)Resource exploration
- ①ISRU (In-Situ Resource Utilization)
- ②Resources with potential for export to Earth (e.g., Helium-3)

(4)Terrestrial industries utilizing lunar environment
- ①Data center
- ②Manufacturing utilizing ultra-high vacuum, low temperature, low gravity
- ③Solar power generation

(5)Potential industries that may emerge independently of lunar infrastructure
- ①Tourism
- ②Advertising and Entertainment



Hot Topic 1 –Lunar data centers current opportunities

Primes: Thales-Alenia involved in a long-term data center project for the Moon, developed in cooperation with NASA/Artemis.

Ventures: U/S/ (Florida) Lonestar Data Holdings raised $5Mn for its future lunar data center project.
In 1Q 2025, Lonestar launched a 1 kg shoebox-size payload on board Intuitive Machines' Athena lander.
Data center embryo with eight terabytes of SSD data storage capacity in partnership with storage company Phison
Commercial partnership with data from internet pioneer Vint Cerf and the government of Florida, among others
Conducted a series of tests including Earth-Moon data transmission and upload of musical videos
By 2027, Lonestar aims to launch a commercial data storage service using satellites placed in the Earth-Moon Lagrange point L1. The satellite hosting this data storage service would have a constant view of Earth to allow continuous data access.

In progress: Earth orbital data centres with edge computing capabilities.
Thales-Alenia ASCEND platforms to be powered by one megawatt of space solar power (ISS solar panels: 240 kilowatts).
Axiom Space station (to set up by 2027 a computing node in low Earth orbit)
Starcloud (formerly Lumen Orbit) raised $21Mn from 2024 to launch a data-crunching satellite with Nvidia GPUs.
Japan's NTT "Space Integrated Computing Network" includes a space data center in orbit, with optical data relay and computing capabilities. JAXA and NTT are currently demonstrating use cases for Earth Observation.

Hot Topic 1 –Lunar data centers business case

Infrastructure backbone for future lunar industry and the cis-lunar economy
Latency reduction, energy/cooling efficiency, sovereign storage
Data edge computing can be performed in-situ on the Moon
Additional business case: use the Moon as a vault - back-up storage for Earth civilization critical data
Potential use of the Moon for non-latency-critical data processing beyond Earth orbit

Demand drivers and key merits:
Data-driven lunar & cislunar infrastructure growth, latency-sensitive applications, possibly Earth data backup and niche services
Autonomy: lunar AI data hubs managing fleets of autonomous robots and spacecraft in cislunar space
Safety and sustainability services: secure lunar command centers managing space domain awareness

Key merits:
Data centers on the Moon combined with efficient edge computing and AI infrastructure lessen the burden of energy consumption on Earth.
Moon-based data centers + edge computing/AI consolidate demand for localised lunar power generation
Diverse customers: governments, space mining and commercial ventures, infrastructure operators, corporate buyers of space-grade data

Challenges: cislunar transportation costs, radiation & dust, repair and maintenance, legal and governance

Conclusion:
Commercial lunar data centers as-a-service could emerge, tied to ISRU, industrial activity, traffic management, and habitat.

Hot Topic 2 –Lunar Helium-3

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- Helium-3 is the critical supply-chain isotope for humanity's AI future
- Virtually unavailable on earth, he-3 exists in "century-long" reserves on the lunar surface
- When used as a fuel for nuclear fusion, he-3 produces zero radioactive waste
- Fusion power promises to solve the global AI datacenter power deficit
- He-3 fusion ideal power source for on-orbit & lunar datacenters
- Fusion power promises "unlimited clean power" at low cost and low impact
- Reconnaissance missions already scheduled (Magna Petra x ispace M3 – H2-2027)
- First sample return aiming for 2030

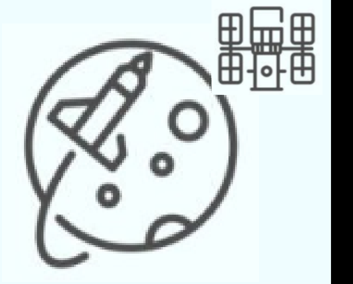
Prediction of Lunar Tourism by Types

■Lunar Orbital Tourism

Start around 2030 once a year at ＄1B for Starship charter flight
2030~ One launch/year with 4 people, $250M/seat
2035~ One launch/year with 10 people, $100M/seat
2045~ A few launch/year with 20 people, $50M/seat
2050~ A few launch/year with 50 people, $20M/seat
One more vehicle start around 2035 once a year at $1B for Blue Moon charter flight with 4 people

■Lunar Orbital Station Tourism

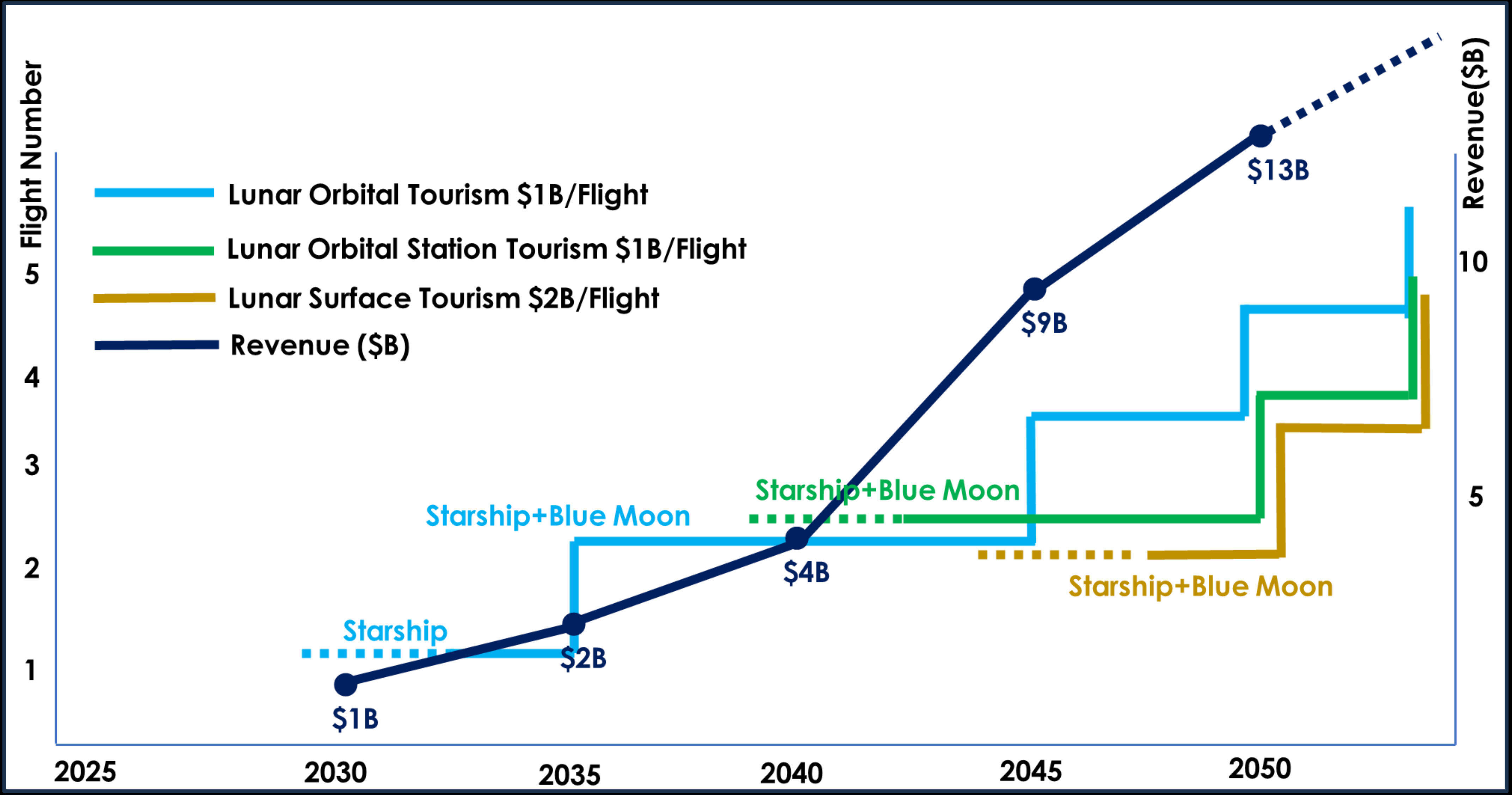
Lunar Gateway for maximum 4 government astronauts
Lunar Orbital Station Tourism will be realized after Lunar Gateway commercialization and/or Commercial lunar stations
Start around 2040 once a year at ＄1B for Starship charter flight
One more vehicle start around 2040 once a year at $1B for Blue Moon charter flight with 4 people



■Lunar Surface Tourism

Start around 2045 once a year at ＄2B for Starship charter flight with 4 people, $500/seat
Around 2050 with 10people, $200M/seat
One more vehicle start around 2045 once a year at $2B for Blue Moon charter flight with 4 people

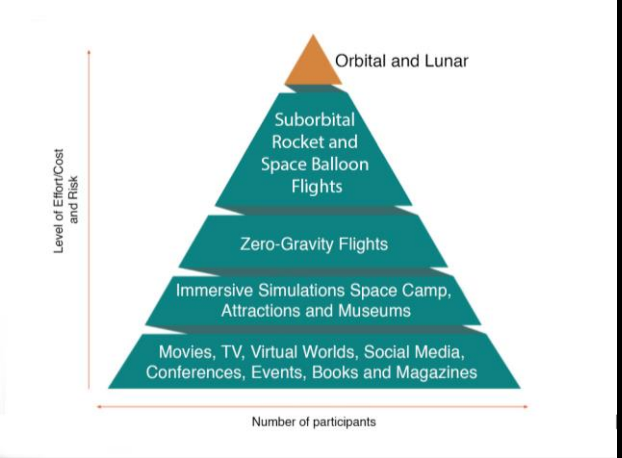
Prediction of Lunar Tourism Market



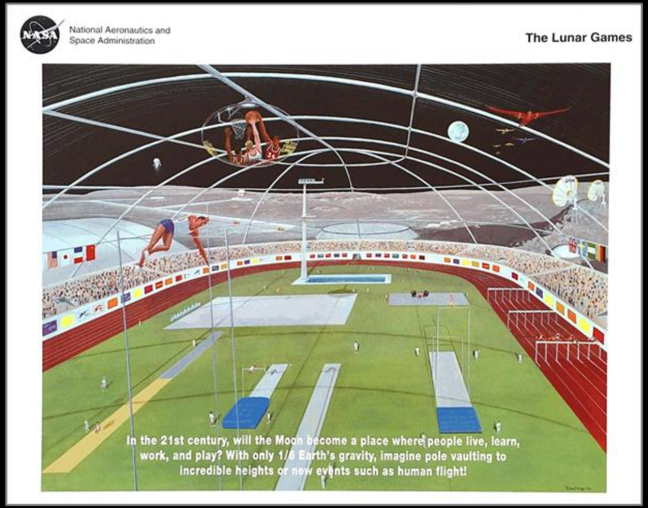
Advertising and Entertainment

- The Moon's unique low gravity and the striking contrast between the Earth and the lunar landscape will create new value and open up unprecedented markets for advertising and sports.
- Market size reference:
  - Global Advertising Market: Approx. $770B
  - Global Sports Market: Approx. $500B

Source:
Ad Spend Dec 2024 - dentsu Global Ad Spend Forecasts Dec 2024
Sports Market Report 2025 - Research and Markets



The Space Experience Economy
Source: https://www.spacetourismconf.com/



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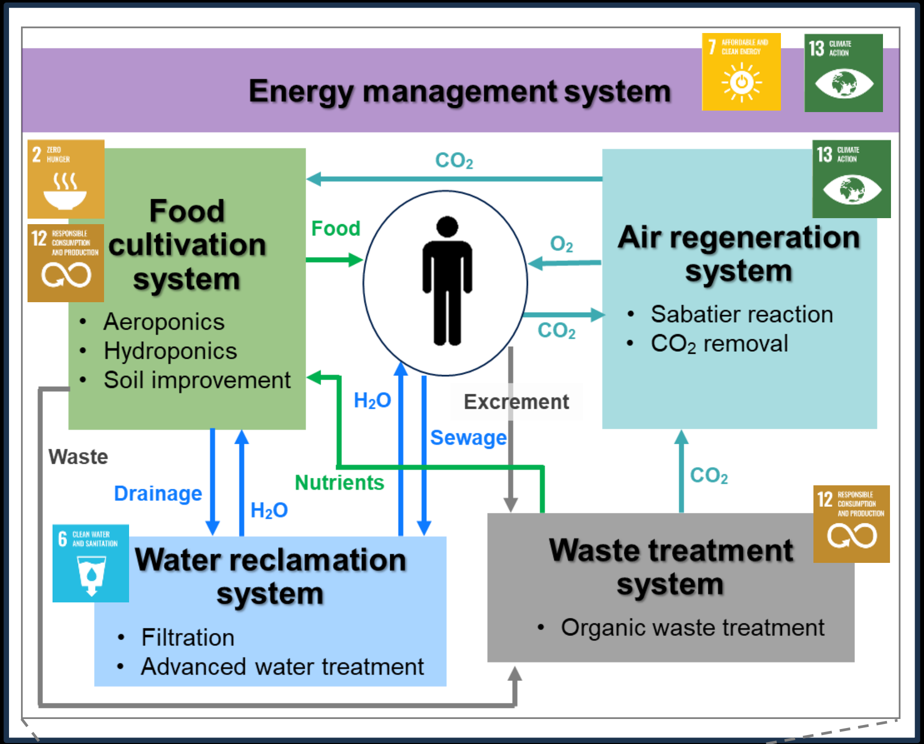
Utilization of space-developed technologies to address major social issues

ECLSS



Technologies developed in the extreme environment like space contribute to…

Challenges on Earth

Space is an extreme environment, and human habitation requires that all air, food, and water be locally produced and consumed

Complete circular ecosystem in space

Source: Kurosu S., Mizuno K., et al.: *Space-enabled Innovations to Solve Earth's Issues*, 76th International Astronautical Congress, (2025)

Space-developed technologies for solving challenges

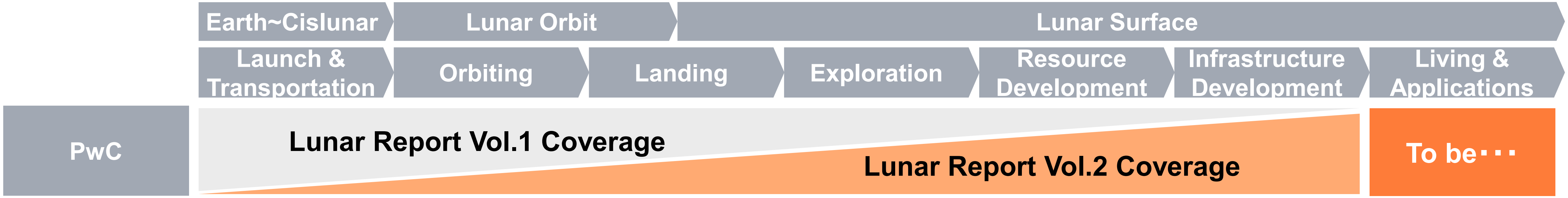
- 13 CLIMATE ACTION: Technologies for removing and capturing CO_2, a cause of global warming
- 7 AFFORDABLE AND CLEAN ENERGY: Technologies enabling efficient, stable, and sustainable energy supply
- 6 CLEAN WATER AND SANITATION: Water recycling technologies using microorganisms and filters, as well as sewage treatment technologies necessary for establishing water recycling systems
- 2 ZERO HUNGER: Effective hydroponic and aeroponic cultivation technologies; Sustainable soil improvement technologies; Technologies for preserving food with its nutrients intact for long periods
- 12 RESPONSIBLE CONSUMPTION AND PRODUCTION: Waste treatment technologies that enable 100% recycling

The Moon as a Catalyst for Earth’s Solutions

- Develop sustainable technologies and insights independent of Earth’s natural ecosystems to address global challenges
- Market size reference (SDGs investment gaps):
  - Energy: $2,200B
  - Water and Sanitation: $500B
  - Food and Agriculture: $300B

Source: SDG Investment Trends Monitor (Issue 4) - Appendix 1: Methodological Note

Overview of Lunar report vol.2



Report Vol.1 (Published in 2021)	• Covers the 20-year period from 2020 to 2040 • Investigated market opportunities in three themes: lunar transportation, lunar data, and in-situ resource utilization
Report Vol.2 (Scheduled for publication in December 2025)	• Covers the 25-year period from 2026 to 2050 (divided into 5 phases, each 5 years) • This report analyzes market opportunities with a focus on lunar infrastructure development. • This report investigates market opportunities for five key types of lunar infrastructure: ①Mobility ②Communication ③Energy ④Habitation ⑤Water

- ✓ **The figures in Lunar Report Vol. 2 appear smaller than those in Vol. 1 due to differences in scope—this edition focuses specifically on infrastructure—and the revision of transportation cost assumptions.**
- ✓ **Because this report focuses solely on infrastructure, the overall market estimates are expected to increase in the future as additional businesses and use cases emerge based on the built infrastructure, including those referenced in the revenue section.**

Estimated Number of Lunar Visitors

As each phase progresses, both the total number of lunar visitors and the peak concurrent population increase. From 2036 onward, we assume that lunar visits by commercial visitors will begin.

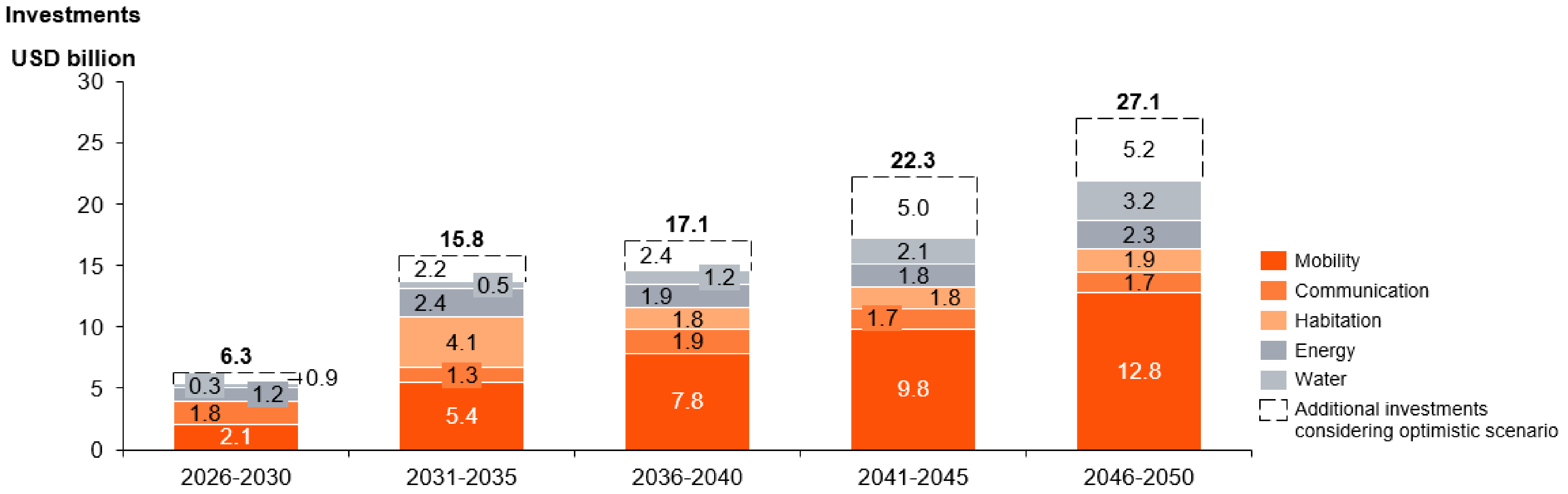
Scenario	Period	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050
Nominal Scenario	Cumulative Number of Visitors	14	32	94	150	248
	Peak concurrent population	4	6	12	18	27
Optimistic Scenario	Cumulative Number of Visitors	14	32	140	234	438
	Peak concurrent population	4	8	16	32	64

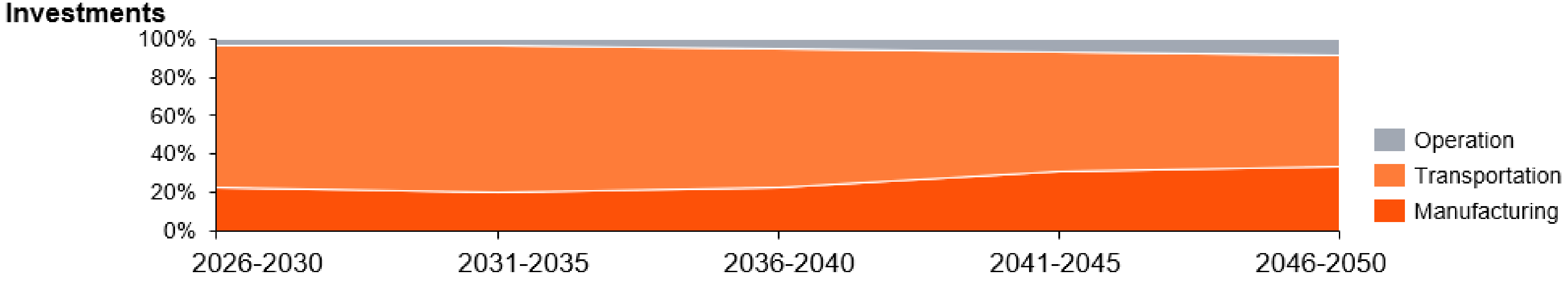
※This refers to the duration of stay on the lunar surface.

*The figures are quoted from the PwC report *"Building the Lunar Economy: Sectorial Forecasts and Market Opportunity"*, scheduled for publication in December 2025.

Market Opportunity (Investment) by Infrastructure Type

The market opportunity for lunar infrastructure is estimated to reach a cumulative total of approximately **USD 73 billion** over the 25-years period from 2026 to 2050 under the nominal scenario, and approximately **USD 89 billion** under the optimistic scenario.

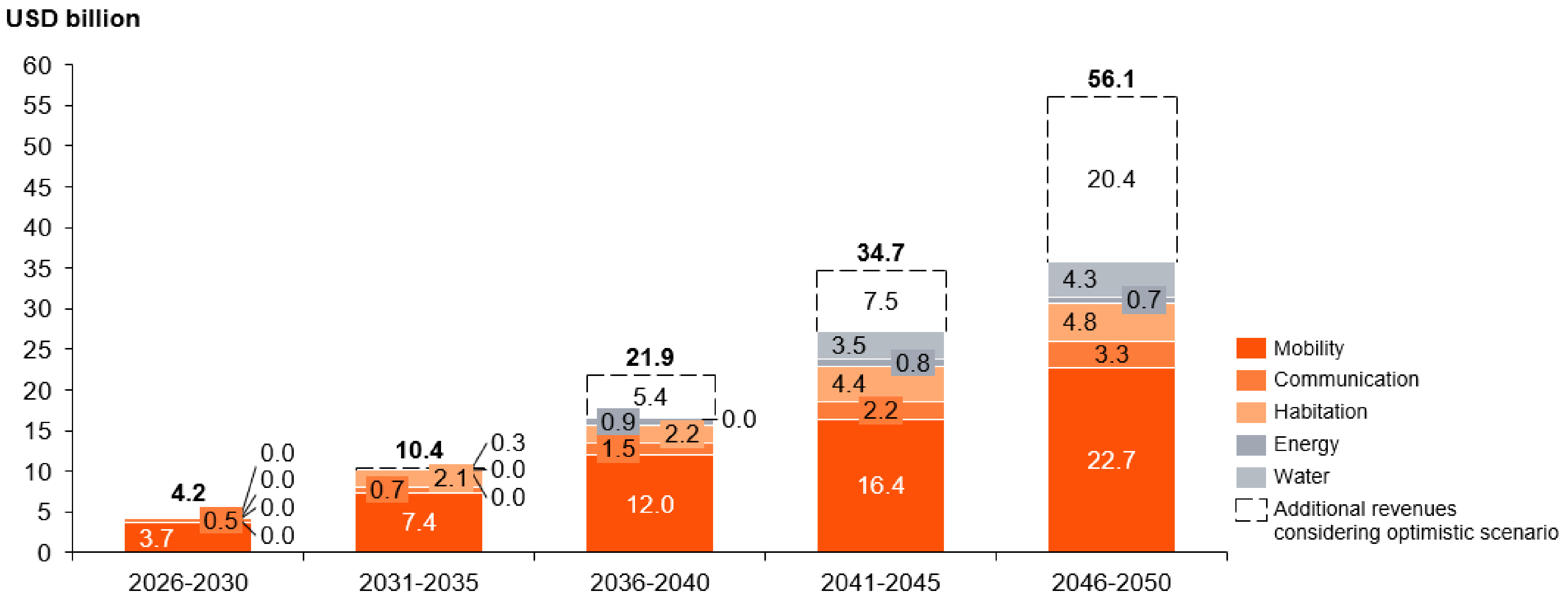




*The figures are quoted from the PwC report *"Building the Lunar Economy: Sectorial Forecasts and Market Opportunity"*, scheduled for publication in December 2025.

Market Opportunity (Revenue) by Infrastructure Type

The revenue opportunity generated by lunar infrastructure is estimated to reach a cumulative total of approximately **USD 94 billion** over the 25-years period from 2026 to 2050 under the nominal scenario, and approximately **USD 127 billion** under the optimistic scenario.



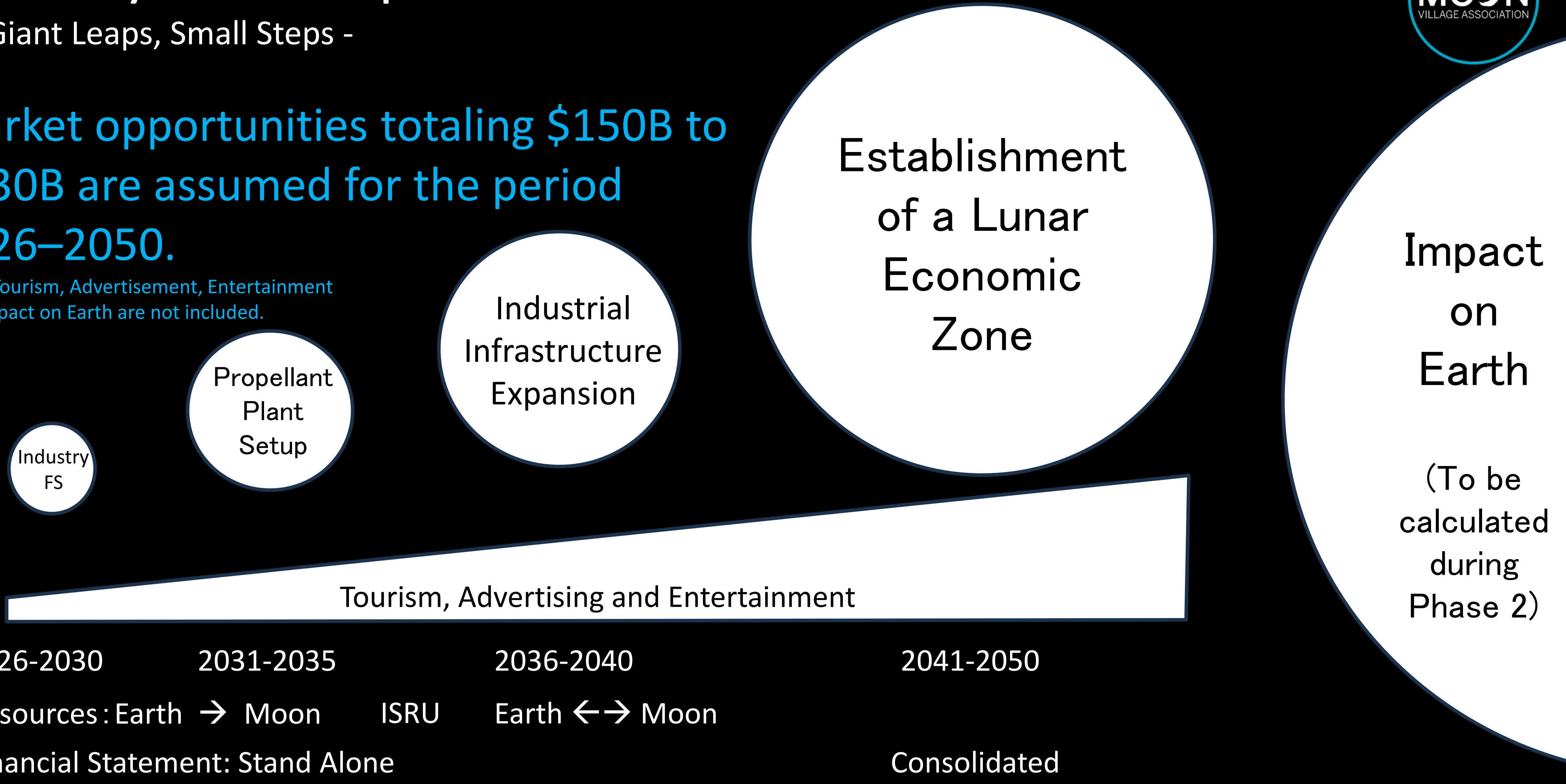
*The figures are quoted from the PwC report *"Building the Lunar Economy: Sectorial Forecasts and Market Opportunity"*, scheduled for publication in December 2025.

Industry Roadmap

- Giant Leaps, Small Steps -

Market opportunities totaling $150B to $230B are assumed for the period 2026–2050.

Note: Tourism, Advertisement, Entertainment and Impact on Earth are not included.



Path to realization
(To be determined during Phase 2)

Examples:

- Large-scale infrastructure developers
- SPC (Special Purpose Company)

Conclusion and the next step

- In Phase 1, we examined the overall landscape of lunar industry segments and the potential benefits for Earth.
- We focused on the propellant plant and found that it can be the "First Small Step" toward Lunar Industrialization.
- In Phase 2, we will conduct a deeper analysis of the overall economic viability and the impact on Earth. In Phase 3, we aim to engage relevant stakeholders to promote realization of these initiatives.

We would appreciate feedback.

Thank you for your attention!

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