OPEN LUNAR FOUNDATION

Scarcity of Lunar Resources

Scorecard and Case Study

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Introduction

If policymakers are serious about pursuing the sustainable development, exploration and utilization of outer space they must start considering the central role scarcity plays. Managing resource scarcity needs to be a prominent goal of the international community for prosperous space economies to flourish. By resisting the notion that there are scarce resources in the face of uncertainty of space resource availability, policymakers are inadvertently supporting an unsustainable path to development; a path that unfairly and unequally benefits the most powerful space actors at the expense of smaller, poorer nations and future generations. As discussed in the policy brief of this scarcity series, the rapid depletion and mismanagement of resources on the Moon and beyond could have undesirable impacts for space exploration and utilization. Environmental degradation, slower economic development, resource depletion and armed conflict were cited, and these are just the tip of the iceberg. More important to focus on is that there are opportunities today to mitigate these issues at the international level. The first step is embracing a system or criteria for acknowledging where and when scarcity is an important consideration.

As explained in "Scarcity of Lunar Resources: Policy Brief", nations, space agencies and other stakeholders can come together to agree that the scarcity of lunar resources is something worth monitoring, and develop basic methods for identifying and calculating scarcity. This is a prerequisite to policy certainty for developing the space economy. A general approach to classifying scarcity could be adopted to prioritize which resources must be conserved first. One possibility is creating a type of "score card" of indicators, such as the estimated supply of the resource or their level of renewability, and generating a "Scarcity Score" that designates which resources are most vulnerable to negative outcomes of unmanaged use.

Objective of the scorecard

Identify scarce resources

The objective of the scorecard is simple: to provide a starting point for evaluating the relative scarcity of specific lunar and outer space resources with current information. Through this evaluation, resource systems that are inherently vulnerable or are at risk of becoming scarce become more visible, and thus easier to prioritize for management. If the resource in question receives a high "Scarcity Score" its management should be prioritized over resources that receive a low Scarcity Score. Use of this scorecard can be applied narrowly (i.e. to specific regions on the Moon) or more broadly (i.e. all orbital slots vs. select latitudes), depending on the user and their respective goals. In the "Comments" section, users are able to provide comments, data or arguments as to why they gave the score that they did, or notes on developments that may alter this score in the future.

Change as information evolves

The scorecard is meant to be a starting point in the process of developing resource management tactics and something that should be built upon over time as our understanding of space resource utilization and scarcity evolves. As we learn more about lunar resources and planned missions, and expand the information and methods used for evaluation, the scores certain resources receive can be systematically updated to reflect new realities. The indicators used in the scorecard are representations of factors known to influence the scarcity (positively or negatively) of resources or to be influenced by scarcity themselves. For example, as the supply of a resource diminishes, or the demand for it increases, the resource becomes more relatively scarce. By accounting for the various factors impacting a resource's abundance, the user gains a better understanding of how scarce a resource is, or can be in the future, and what factors should be focused on to prevent its depletion.

Although this evaluation method can be subject to bias, there are ways to reduce the levels of subjectivity to a reasonable point where the scores are still universally valid. For example, several experts from different backgrounds can evaluate a specific resource and their scores can be averaged together to form a score that reflects the difference in opinion. However, the point of the score is to figure out which resources need managing first, not to provide an exact detailed measurement of scarcity.

Scarcity Scorecard		
Resource:		
Variable	**Influence (0 - 2, 0 = low/no influence, 2 = high influence)**	**Comments/Notes**
Excludability		
Rivalry		
Renewability		
Supply		
Demand		
Accessibility		
Feasibility of management		
Technology/Market factors		
Potential for conflict		
Timeline		
Total Score		

Variables Explained

Excludability: If access to the resource can be prevented in some way (by use, extraction, ownership, occupation etc.) it would be considered excludable[11]. Excludability can also alter the conditions or rate upon which goods are consumed. Excludable resources can create competition among actors, making the resource more sought after, but it can also dictate who and how many people can use a particular good - which can be helpful in regulating their use. As non-excludable resources can be consumed by anyone at any time, they are often prone to overconsumption. Legal excludability through property rights, for instance, can prevent use patterns of unmitigated accessibility and unsustainable consumption. Therefore, the more excludable a resource is the lower the score it should receive.

Rivalry: A rival good is a resource that can only be possessed, used or consumed by a single user and/or will perish upon its consumption[12]. An apple, for example, is rivalrous for if I eat the entire apple there will be none left for others to consume. When goods are consumed upon utilization, they have the potential to be rapidly depleted by users, which will naturally affect their abundance and incentivize competition amongst actors who wish to possess a resource before others do. Therefore, a resource that is rivalrous should be given a higher score on the scorecard.

Renewability: This evaluates if the resource in question is finite or renewable, and if it is renewable, how quickly this resource regenerates. Those resources that are unable to be replenished, or replenish at a slower rate than they are being consumed, will be more prone to scarcity. A higher scarcity score should be given to those resources that are unable to regenerate or their supply recovers very slowly.

Supply: This indicator refers to the known or speculated amount of a resource that exists. Supply is typically considered in relation to the demand for a specific resource. Intuitively, as resources become less abundant they by default become more scarce, and, there could be multiple factors that influence both the current and future level of supply. On the scorecard, less abundant resources should be given a higher score. If the level of supply is currently unknown and/or difficult to estimate, a score of zero should be given.

Demand: Evaluates the level of desire for a resource, or how much of it is expected to be acquired and utilized by space actors. As the demand for a resource grows, the incentive to exploit the resource also increases, which can negatively impact its future availability. Resources in high demand should receive a higher score on the scorecard; if demand is non-existent or currently unknown, a score of zero should be given

Accessibility: Refers to how easy it is for actors to acquire, occupy and/or physically get to the resource in question. Those resources that are highly accessible (meaning anyone can theoretically get there and use the resource if they wanted to) are more susceptible to depletion and should be given a higher score.

Feasibility of Management: This indicator looks at how complicated it would be to manage this resource or how simple it would be to regulate its acquisition and utilization. The resources that are most difficult to manage should be given a higher score as they will be comparatively harder to create conservation plans for.

Technology/Market Factors: Concerned about any developments in technology or markets that could affect the other scarcity indicators. For example, if there has been a recent breakthrough in lunar mining equipment that will make acquiring lunar ice easier, it can affect the accessibility, demand and supply of lunar ice. Those resources that have an established competitive market, or whose exploitation has been made easier by recent technological advancement, should be given a higher score.

Potential for Conflict: Here, the user looks at how likely it is for conflict (armed or non-physical) to arise due to the increased scarcity of the resource in question. The importance of the resource to future missions, a lucrative market price, lack of regulation, and strategic positioning, to name a few, are all factors that could inspire conflict over resources. Those resources with the potential to inspire conflict as they become more scarce, or those where conflict could influence their scarcity (i.e. debris from ASATs making orbital slots unusable) should be given a higher score.

Grading	
Score	**Risk of Scarcity**
0 – 4 points	Low risk: resource is widely abundant with little or no competition, will be available in the future with minimal management, highly unlikely source of conflict; minimal management required at this time
5 – 9 points	Medium risk: there is growing competition for this resource, future supply may be compromised without regulation, possible source of conflict; management strategy is required
10 - 13 points	High risk: moderate competition for this resource, expected future depletion without regulation, reasonable source of conflict; stronger management strategy required
14+ points	Very high risk: Intense competition over very limited supply, expected depletion in the near future, strong source of conflict; strict management strategy needed imminently

Scoring System

Each of the nine indicators should be carefully examined to determine their ability to affect a resource's level of scarcity. Users give a score of 0, 1 or 2, depending on their level of influence, for each indicator with 2 being the highest score and 0 being the lowest. The indicators that contribute significantly to resource scarcity should be given a higher score, while those factors that have little to no effect over whether a resource becomes scarce should be given a lower score. Respective scores are tallied up at the end to give a total, which will ultimately be the resource's "Scarcity Score".

Using the Scarcity Score and provided grading system, users can determine how scarce one resource is compared to others. Those resources that receive a scarcity score of 4 points or less should be considered at "low risk" to become scarce, and therefore needs less stringent or immediate management; meanwhile, those resources that receive a score of 14 points or higher should be considered in need of urgent and strict regulation to prevent their depletion.

Scarcity Scorecard Case Study: Lunar Water Ice

Scarcity Scorecard		
Resource: Water Ice on the Moon		
Variable	**Influence (0 - 2, 0 = low/no influence, 2 = high influence)**	**Comments/Notes**
Excludability	1	Depending on its physical location, water ice can be an excludable resource to those without the ability to acquire it. But currently, anyone with the ability can theoretically acquire unlimited amounts of water from the Moon.
Rivalry	1	Due to its importance for future space missions, several space actors are expected to compete to acquire and use lunar water ice in the future[1]. Water, depending on its use, is likely to be consumed as it is acquired and therefore has the potential to be depleted if supply is not carefully monitored and managed.
Renewability	2	The ice on the Moon, most of which is locked in cold, permanently shadowed regions or comes from the bombardment of meteorites, regenerates unpredictably and very slowly (if at all)[2].

Supply	1	It is predicted that over 600 billion kilograms of water ice exists on the Moon, which is quite a lot; however, most of it is difficult to access which may restrict the current supply of available water ice[3]. Lunar water supply could be supported by improved water extraction and recycling techniques, but could also be threatened by its consumption as rocket fuel.
Demand	1	The demand for ice is currently low, but several space actors have planned missions to acquire water ice in the near future[4].
Accessibility	1	Much of the water ice on the Moon, though predictably abundant, is currently difficult to access; however, there are places on the Moon that water is easier to collect from the surface[5].
Feasibility of management	1	It is certainly possible to regulate aspects of water ice supply (i.e. restrict amounts collected or only mining specific locations) but challenges do exist, and could persist into the future
Technology/Market factors	0	The technology to extract, refine, and use water ice is currently being developed and tested by several space actors, however, many of these are prototypes in their infancy and untested in the field[6].
Potential for conflict	1	There currently is no conflict related to the physical acquisition and use of water ice on the Moon, but there is contentious debate about the legal right to extract and use space resources; due to its high importance in future deep space missions and development of lunar colonies, water ice has the potential to become highly coveted and a source for conflict.[7]
Total Score	9	

The above is a short case study of how the Scarcity Scorecard might be applied to evaluate the scarcity of lunar resources – in this case, water ice on and beneath the Moon's surface.

Interpreting the Results

Ice has been discovered on the Moon, and since then, our knowledge about how much exists, where it is located and what we can do with it is constantly expanding[8]. While the existence of water on the Moon is fantastic news for future space exploration, the importance of water ice makes it a resource that many space actors are looking to acquire. Currently, the demand for water ice is low, but it is projected to increase considerably as space programs mature and the space industry develops. High levels of consumption could eventually place a strain on lunar water supplies, especially if large segments of the water ice supply are inaccessible as many scientists suggest[9].

In addition to the necessity of water for future space missions, its rivalrous characteristics, and its limited accessibility, the acquisition of water could also offer a strategic advantage to space actors. It is not a stretch to predict, as many experts have, that some actors will seek to stockpile reserves of water ice for geopolitical influence, much like what happens with many natural resources on Earth[10]. This added incentive to collect and utilize water ice on the Moon is certain to affect the scarcity of this resource and should be considered a potential source of conflict between space actors. The results from the Scarcity Scorecard seem to reflect this reality of water ice quite well. With a score of 9, it falls under the "Medium Risk" category, signifying that this resource is a prime candidate for a resource management strategy to be developed, but not at the point where the resource is at risk of depletion.

Important to understand about the scorecard is that these scores or values are not static; they can, and likely will, change over time as humanity further explores space and expands its capabilities. While there currently is minimal competition, consumption, and conventional markets for lunar water ice, planned future missions suggest this will change in the near future. So, although water ice is in the Medium Risk category now, it can very easily move into a higher risk spectrum, increasing the priority to regulate it. Conversely, if policymakers take steps now to manage the acquisition and use of water on the Moon, we may be able to use it sustainably for many generations.

Overall, it is not time to panic about the scarcity of water ice on the Moon, but it is a logical time to start planning for its sustainable management. Being in the middle of the scarcity spectrum, and considering its importance to future space exploration, policymakers would be wise to take action now to prevent future depletion and prevent water from becoming a new source of conflict.

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