DATA NEEDED TO SUPPORT QUANTITATIVE LUNAR RESOURCE ASSESSMENTS. L. P. Keszthelyi[1], T. S. Gabriel[1], L. R. Ostrach[1], K. A. Bennett[1], and J. A. Coyan[2] [1]U.S. Geological Survey, Astrogeology Science Center (2255 N. Gemini Dr., Flagstaff, AZ 86001, laz@usgs.gov), [2]U.S. Geological Survey, Geology Minerals Energy and Geophysics Science Center.

The methods used by the United States Geological Survey (USGS) to assess energy and mineral resources on Earth provide a framework for quantitative lunar resource assessments (QLRA) [1,2]. Here we consider what new information is needed to complete such assessments for six resources, two each within energy, minerals, and water. These were chosen to be representative of a variety of lunar resources.

Energy, Solar. The existing ephemerides and topographic data are adequate to assess the quantity and quality of solar energy across the surface of the Moon. However, higher resolution topographic and geotechnical data may be needed to meet the landing and deployment requirements for any landed ISRU effort.

Energy, ^3He. Apollo samples are adequate to estimate the abundance of ^3He in the regolith globally. While additional samples would reduce the uncertainties in an assessment, the main uncertainty is when ^3He will become a commodity.

Mineral, Bulk Regolith for Construction. Apollo seismic data and core samples, supported by orbital thermal, radar, and geomorphology studies allow bulk regolith to be assessed globally with roughly a factor of two uncertainty in parameters such as regolith depth. Additional *in situ* data from polar regions where ices may alter the regolith thermophysical properties would be helpful but Apollo 16 data provide a good baseline.

Mineral, O_2 from Regolith. The combination of Apollo samples and orbital spectroscopic data (gamma ray, ultraviolet, infrared) provide excellent constraints on the geochemistry and mineralogy of lunar regolith, allowing an assessment for oxygen extraction for a variety of volcanic and highland terrains.

Water, Bound H/OH. Apollo samples and remote sensing data show that hydrogen and hydroxyl bound to the regolith is quite variable, but appears highest in some lunar pyroclastic deposits. The variation toward the poles is also uncertain. Assessments are possible with the current data, but uncertainties would be quite large. Even a modest number of new regolith samples from the locations where ISRU is contemplated would substantially reduce these uncertainties.

Water, Ice. There is a critical lack of *in situ* data from the polar regions to test geologic models and construct preliminary deposit models. NASA's *VIPER* mission will directly address this problem [3]. It is a reasonable expectation that some types of ice deposits will prove simple enough to quantitatively assess after *VIPER,* but it is also plausible that some forms of ice will have a more complex distribution that will require additional in situ investigation.

Conclusions. Many lunar resources can be assessed to identify highly favorable areas with the existing data. A few samples returned from polar regolith would substantially reduce uncertainty in the assessment of multiple resources. However, in all cases, it is prudent to conduct a detailed (decameter to decimeter scale) survey of the specific site where ISRU activities are to take place. The spatial resolution of current topographic data is marginal; for thermophysical and geochemical properties, it is inadequate. Landed missions capable of trenching and dense drilling are required to characterize the subsurface distribution of resources on a scale relevant to excavation (cm to meters).

This suggests that a resource exploration campaign can build on the *CLPS* and *VIPER* missions with a modest number of samples returned from polar regions (or comparable measurements made in situ). This would allow confident identification of sites highly favorable for ISRU. The selected site(s) must be investigated in detail with landed mission(s) to determine the feasibility of extracting the resource and mitigating the impact of the extraction activities. Note that *reserves* (i.e., resources that can be converted to a commodity within the available mass, energy, volume, time, cost, and risk budgets) depend on the specifics of the ISRU mission.

References: [1] Keszthelyi L. et al. (2019) *Space Res. Roundtable 2019*. [1] Keszthelyi L. et al. (2021) *Space Res. Roundtable 2021*. [3] Colaprete A. et al. (2022) *Lun. Planet. Sci. Conf., 53*, Abstract 2678.

Table 1. Applicability of the QLRA methodology to six representative lunar resources. TRL stands for Technical Readiness Level.

	Geologic Model	Deposit Models	Technical and Economic Models
Solar Energy	Validated	Yes, minimal uncertainties	High-TRL
^3He	Validated	Yes, modest uncertainties	Low-TRL
Bulk Regolith	Validated	Yes, modest uncertainties	Mid-TRL
Regolith O_2	Validated	Yes, minimal uncertainties	Mid-TRL
Bound H_2O/H	Multiple, some validated	Yes, large uncertainties	Low-TRL
Ice	Multiple, none validated	Only hypothetical	Low-TRL