Maestría en Regeneración y Desarrollo Sostenible

Materia: Aplicación de la economía circular

Samuel Byrne Belliel 12.10.2025

From May 2020 until December 2023, I worked as a Fluid Systems Engineer for Blue Origin. Blue Origin's mission is to build "a road to space for the benefit of Earth" (Blue Origin). Although I worked on the New Glenn rocket, I had coworkers that worked on the New Shepard (NS) rocket and that will be the focus of this paper on Circular Economy.

At a high level, NS is a tourism and space research rocket that launches from Van Horn, Texas for a roughly 12-minute total ride to space. The program is largely seen as wasteful and an expense exclusive to the uber rich – unknown ticket prices estimated at $1 million or more (Firstpost, 2023). Putting aside the moral ambiguity of this launch vehicle, the vehicle was designed to operate with 99% reusability.

One of the largest environmental concerns with this rocket system is the amount and type of fuel that it requires. As NS uses liquified oxygen and liquified hydrogen, there is no hydrocarbon exhaust at the point of combustion, although anthropocentric water vapor in the upper atmosphere is still being studied for its detrimental effects to climate change (BBC Future, 2022). What is certain, however, is that the liquid hydrogen (LH_2) that it does use is dirty throughout production and distribution. 95% of commercial LH_2 is produced from liquified natural gas (LNG) and then transported via diesel truck throughout the US. (U.S. Department of Energy). To make matters worse, LH_2 is continually lost due to ambient leakage throughout transportation and distribution while it is expensive at around $20/kg (CleanEpic).

<u>Circular Economy Initiative – Costs of Inefficiency</u>

With the above in mind, there is a major cost of inefficiency present at Blue Origin for the NS launch vehicle. This cost of inefficiency opportunity will bring in part of the inefficient supply chain to leverage renewable energy and improve efficiency overall while driving economic and environmental benefits.

The proposed initiative is to develop a small-scale liquified hydrogen facility powered by solar panels in replacement of trucking in LH_2. The Van Horn launch complex is large and wholly owned by Blue Origin – this provides ample space for a solar farm and a small LH_2 facility. This initiative leverages the existing storage tank and people knowledge systems that Blue Origin uses to receive and handle LH_2.

The proposed initiative is a circular business model through its transition to renewable energy in place of a carbon-intensive and dispersed network resource. Launch vehicles are historically not sustainable but, "according to UNOOSA and ESA's joint contribution to the Space2030 Agenda, space technologies have the potential to facilitate the achievement of all 17 SDGs" (Welchman Keen, 2024). Although this specific initiative will largely just benefit Blue Origin and the environment, it can be seen as a pilot project for launch vehicle systems worldwide.

Details of initiative

To begin this analysis, it was essential to understand the operating space that NS works within. The table below details the inputs for this rocket system with the amount of LH_2 needed per flight, the number of expected flights per year, and then the calculated total amount of need LH_2. As LH_2 is a commodity and the price varies based on the market, a mid-range value of $20 per kilogram of LH_2 was determined (CleanEpic).

Inputs		
Name	Value	Unit
Amount of LH_2 for a flight	3,000[9]	Kg of LH_2
Rounding and with spare	5,000	Kg of LH_2
Flights/year	10[12]	flights/year
Annual need	50,000	kg of LH_2.
Cost of currently delivered LH_2	20[6]	$/kg of LH_2.

Table 1.

With the inputs defined, an LH_2 production plant was sized for this facility. A recent Air Liquide LH_2 facility was developed with 30 tons of LH_2 per day at roughly $250 million – this would have been overkill for the small need of Blue Origin's NS rocket and a 300kg/day was sized to meet the needs of the program. A calculation was then performed to determine the size of a solar farm to feed this liquification plant and it came out to only 450kW.

New 300 kg/day plant		
Name	Value	Unit
Capital Expenditures (CapEx)	2.5[1]	Million USD
Operational Expenditures as a function of energy	3600[6]	kWh
Solar farm energy output est.	8	hours/day
Required minimum size of solar farm	450	kW
Solar farm		
CapEx cost of Solar Farm per watt	0.98[11]	$/watt
Solar farm cost 450 kW	$ 441,000.00	
Total		

Total CapEx	$ 2,941,000.00	

Table 2.

It is important to note that the above does not include non-electricity operating costs. The costs associated with managing and employing employees to facilitate both the Solar Farm and the LH_2 plan were determined low enough to ignore. As detailed in table 2, the small LH_2 plant and solar farm has an estimated cost of 2.941 million USD.

The table below highlights the environmental costs associated with the current LH_2 trucking system. This system is defined as 2 semi-trucks loaded with LH_2 driving round trip from Houston to Van Horn, Texas and the corresponding emissions. Further below the conventional natural gas (NG) greenhouse gas (GHG) emissions are calculated for this size of operation.

Environmental costs of transportation of LH2		
Name	Value	Unit
Max amount of LH_2 per truck	4608[5]	kg
Number of trucks per launch	2	Trucks
Fuel	6[15]	mpg
Houston to Van Horn**	626	miles
	104.3	Gallons per trip
	417.3	Gallons per 2 round trips
Total gallons of diesel per year (10x flights)	4173.3	gallons
CO2 emissions of burned diesel	22.4[2]	lbs/gallon
Total CO2 emissions in lbs	93482.7	lbs
CO2 emissions per year tons of CO2	42.4	metric tons of CO2
Conventional NG GHG emissions		
Emissions per kWh	550[10]	g CO2e/kWh
kWh needed	600,000	kWh
	330	metric tons of CO2
Total		
Total emissions avoided	372.4	metric tons of CO2 / year

Table 3.

Benefits and Impact

Through the implementation of this initiative Blue Origin can expect to have the qualitative and difficult to measure benefits defined below as well as the economic and environmental benefits highlighted later:

- The CO_2 reductions map to Scope 1 (substitution of fuel in situ) and Scope 3 (elimination of the transport of LH_2), aligning the organization with SBTi and the UN's SDGs 7 and 13.
- Reduction of diesel emissions from LH_2 transportation nearby work sites will improve health outcomes for workers
- Unlinking itself to the global price fluctuations of production and transportation of LH_2
- Integration of LH_2 processing will increase efficiencies for the total operation by removing the need for third parties.
- Accurate accounting of methane leakages and complete carbon footprint.
- Reputation improvement showing Blue Origin as a company committed to sustainability.

Furthermore, the table below highlights the impressive economic benefits of this new LH_2 plant. The implementation of a small-scale LH_2 + solar farm has the potential to pay for itself in under 3 years and thereafter saves the company $1 million a year.

Economic Benefits		
Name	Value	Unit
Current system annual cost	$ 1,000,000.00	Per year
Circular Economy Solar farm + Hydrogen Liquefier Initiative	$ 2,941,000.00	One time
Payback time	36	Months

Table 4.

Finally, the table below shows the environmental benefits of this cleaner production initiative. Like the above economic benefits, there exists an initial period where the emissions are increased, however, this is quickly followed by a reduction in total emissions of the operation.

Environmental Benefits		
Name	Value	Unit
Metric tons of CO2 burned during construction of new LH_2 plant (estimated).	294[8]	metric tons CO2
Annual emissions avoided	372.4	metric tons of CO2 / year
Payback time	16	months

Table 5

<u>Barriers and Further Research</u>

With the above said, there are some known caveats to this research and ways that it can be increased further. To begin with, certain values (like operating expenditures due to wages) were neglected as well as the potential financial costs associated with undertaking these initiatives (borrowing rates, one-time fees, etc.). Additionally, as a barrier to implementation there is much work needs to be done to ensure that this LH_2 plant can safely be constructed near a rocket launch facility and that can proceed with current regulatory frameworks. Finally, a facility of this size has not been done commercially before and there would be some significant learnings involved.

The implementation of this initiative would require interfacing corporate governance departments (operations, security, finance, and compliance among others) which can improve capacities for scaling.

To improve the initiative in the future, the plant could expand from taking LNG as an input to having more solar panels and use electrolysis to create hydrogen gas and then compress it thereby leveraging green hydrogen. This could have significant benefits as storage of hydrogen gas is less energy intensive than LH_2 as it doesn't need to reach -240^{0}C.

Conclusion

Overall, this initiative is promising as a way of drastically reducing both carbon dioxide emissions and economic expenditures of the Blue Origin NS launch vehicle system. This initiative leverages the cleaner production synergies of the knowledgeable workforce already employed by Blue Origin and the advantages of renewable energy on-site to reduce the costs of inefficiency. Technological and market barriers exist, but with further research this initiative will carry Blue Origin to meet its mission of benefiting the Earth.

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Appendix

A1. New Shepard Launch Vehicle at the Van Horn Launch Complex

(Blue Origin)